

**Final  
Geotechnical Investigation and  
Pavement Design Report**

**Wichita Mountains National Wildlife Refuge  
Project: OK RRP WIMO 10(1)  
Routes 10 and 11**

**Project No. 28-238  
Revised 4-7-10**

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## Purpose and Scope of Study

This report presents the results of our subsurface investigation and pavement design recommendations for the improvements of Routes 10 and 11 in the Wichita Mountains National Wildlife Refuge (NWR). The planned improvements are to add paved shoulder sections on approximately 3.3 miles of Route 10 between Mile Posts 4.6 and 7.9, and on 1.9 miles of Route 11 between Mile Posts 0.0 and 1.9 for a total of 5.2 miles of construction. The report also provides foundation recommendations for the pedestrian bridge on the Elk Mountain Trail.

The scope for the pavement design and geotechnical investigation includes the following:

- Explore the subsurface conditions along the proposed alignments and at the bridge abutment locations.
- Perform geotechnical laboratory testing on selected subsurface samples.
- Evaluate and summarize the field and laboratory data obtained.
- Recommend suitable Hot Asphalt Concrete Pavement (HACP) shoulder thickness.
- Provide foundation design and construction criteria for the pedestrian bridge.

## Proposed Construction

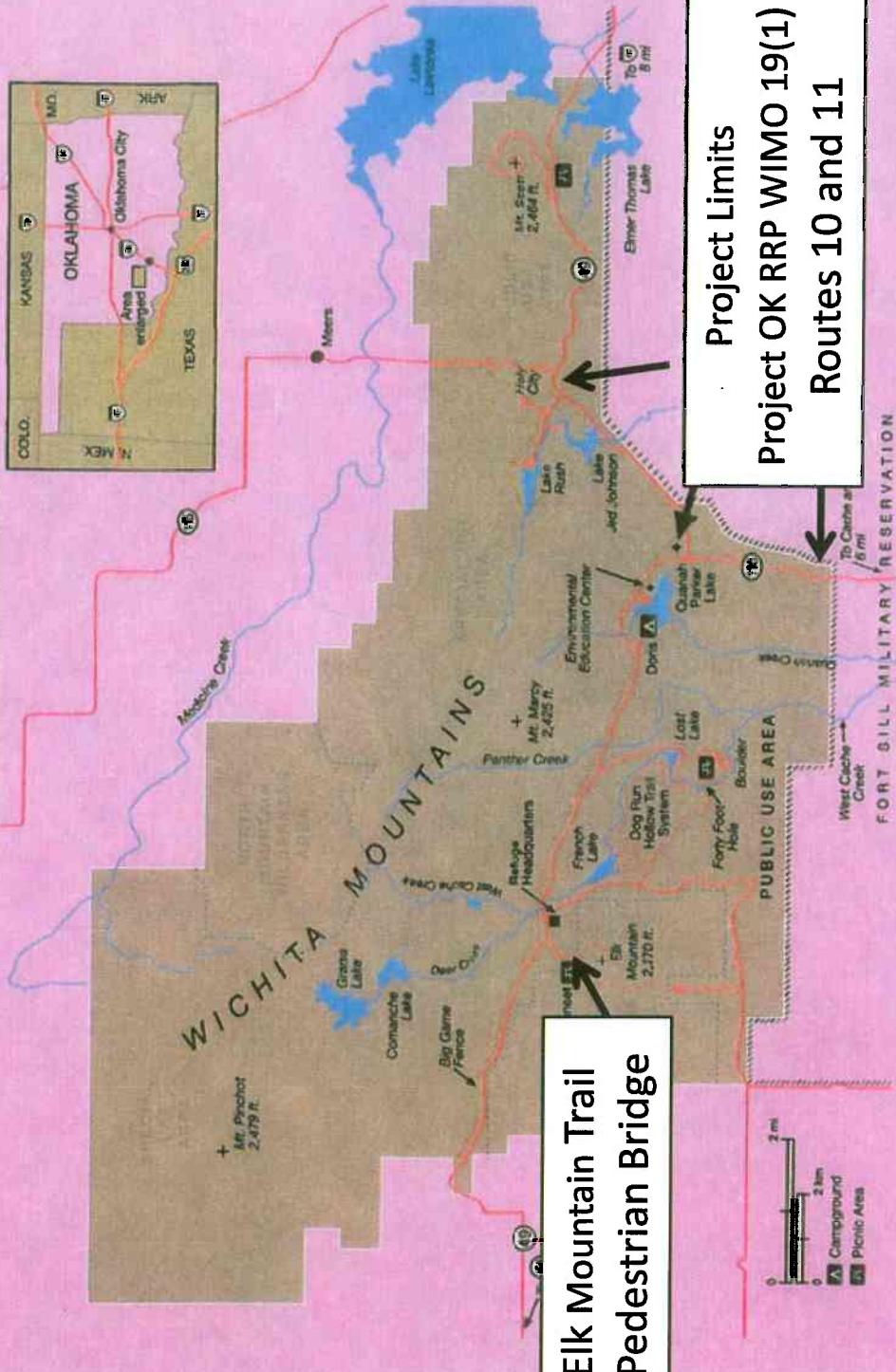
The planned construction will primarily include widening the existing typical roadway section to provide shoulders on both sides of the roadway. The minimum typical width of the shoulder will be seven feet. The widened shoulder will closely follow the horizontal alignment, vertical alignment, and cross slope of the existing roadways. No reconstruction of the existing roadway section is anticipated.

The proposed improvements also include replacing the existing bridge on the Elk Mountain pedestrian trail with a new steel truss single span bridge and the pedestrian trails leading to the new bridge.

## Site Conditions

The project site is located along NWR Routes 10 and 11 (Oklahoma State Routes 49 and 115 respectively) inside the Wichita Mountains NWR (See Figure 1). The existing roadways are two-lane asphalt pavements in fair to good condition with few signs of major distress or subgrade failure. The subgrade is primarily clayey sand and thick prairie grass is

**Figure 1**  
**Project Location Map**



growing up to the edge of pavement and few erosion problems were noted. Route 10 has more cracking than Route 11. Neither of the roadways has shoulders and the grass is tall right to the edge of pavement. Drainage from the pavement is carried across the existing pavement into ditches on either side of the road. Figure 2 shows one distressed pavement location on Route 10 with edge cracking and some low severity linear transverse cracks and the center line longitudinal joint is slightly open. These cracks and joints have all been sealed.

**Figure 2 – Route 10 Severe Edge Cracking**



Figure 3 shows a more typical section of Route 10 with low severity linear cracks which have also been sealed.

**Figure 3 – Route 10 Typical Cracking**



Figure 4 shows a typical section of Route 11, with the major distress in the center line and other longitudinal joints. These joints have also been sealed. Only localized linear cracking has occurred on Route 11 in the project area.

**Figure 4 – Route 11 Typical Good Condition**



Since this project is to construct new shoulders, the existing shoulders on Route 10 and 11 were reviewed to determine their condition and performance. Figure 5 shows typical shoulder condition near the project location, note that the mainline has been overlaid but not the shoulders.

**Figure 5 – Route 10 Typical Shoulder Condition (outside of project limits)**



On Route 11, the mainline has also been overlaid and the shoulder not treated. The major distress on the shoulder in this location is longitudinal cracking.

**Figure 6 – Route 11 Typical Shoulder Condition (outside of project limits)**



There are some isolated locations with more severe deterioration as shown in Figure 7.

**Figure 7 – Shoulder Deterioration along edge of pavement**

## **Geologic Setting**

The Wichita Mountains consist of two rugged granite mountain ranges enclosing a natural prairie. Several episodes of land settlement in the early and mid Cambrian time (500 to 600 million years ago) allowed disposition of clay, rocks and sand which caused the formation of some sandstone, now mostly eroded away. These settlements were followed by several episodes of lava flows forming the gabbro and granite that can still be found in numerous places within the Refuge.

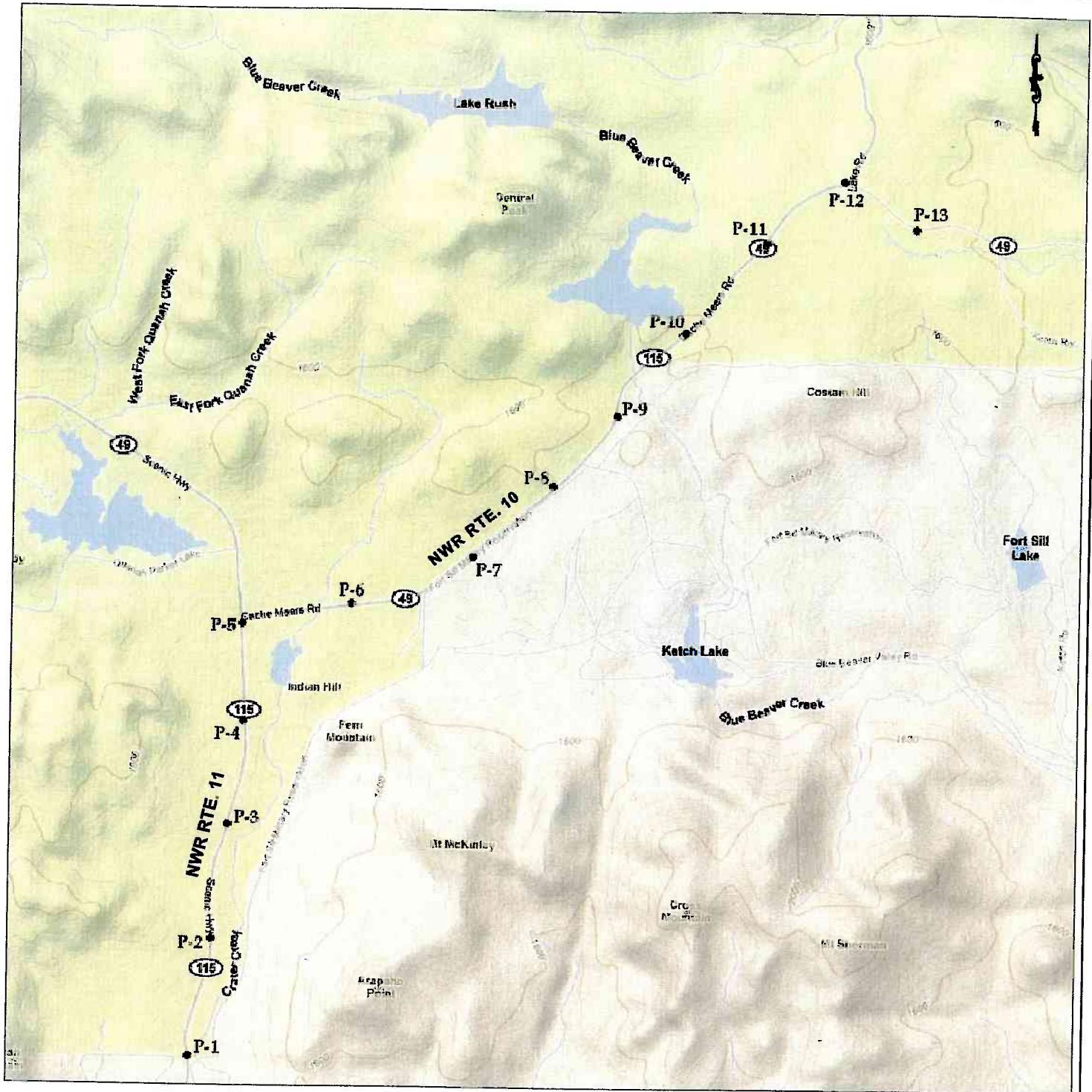
The mountains of the Wichita region were formed some 300 million years ago (Pennsylvanian period). They were created by a tremendous uplift accompanied by large folds and faults. They were considerably higher, but erosion has stripped off the upper parts and deposited this material in the flats making the mountains less steep. Mount Pinchot and Mount Scott were formed during this period. The two tallest mountains are Mount Scott with an elevation of 2,464 feet and Mount Pinchot with an elevation of 2,479 feet.

## **Seismic Activity**

Based on the AASHTO LRFD Bridge Design Specifications [2008 Interims (Table 3.10.3.1-1)], the site (Lawton, Oklahoma) classifies as a class D for seismic loading. According to the USGS Seismic design Parameters software (Version 2.10) a factored peak ground acceleration (PGA) of 0.06g g (g = gravity) may be used for this site with a 7% probability of exceedance in 75 years (Approximate 1000-year Return Period Outlined by AASTHO). The probably of seismic activity being a factor on this project is very low.

## **Pavement Subsurface Investigation**

For the pavement investigation, thirteen exploratory borings were drilled along Routes 10 and 11. The borings were spaced approximately one-half mile apart and were alternated between sides of the pavement. A map of the approximate boring locations appears in Figures 5A and 5B. Several borings were taken through the existing HACP to measure the pavement thickness. Table 1 lists the pavement thickness for those borings taken through the pavement.



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**Sheet Revision**

Date	Revision/Issue	Checked by

Designed For:

HDR Inc.

Project Number:

28-238

Drawn by: MDN

Date:

December 3, 2008

Checked by: RFL

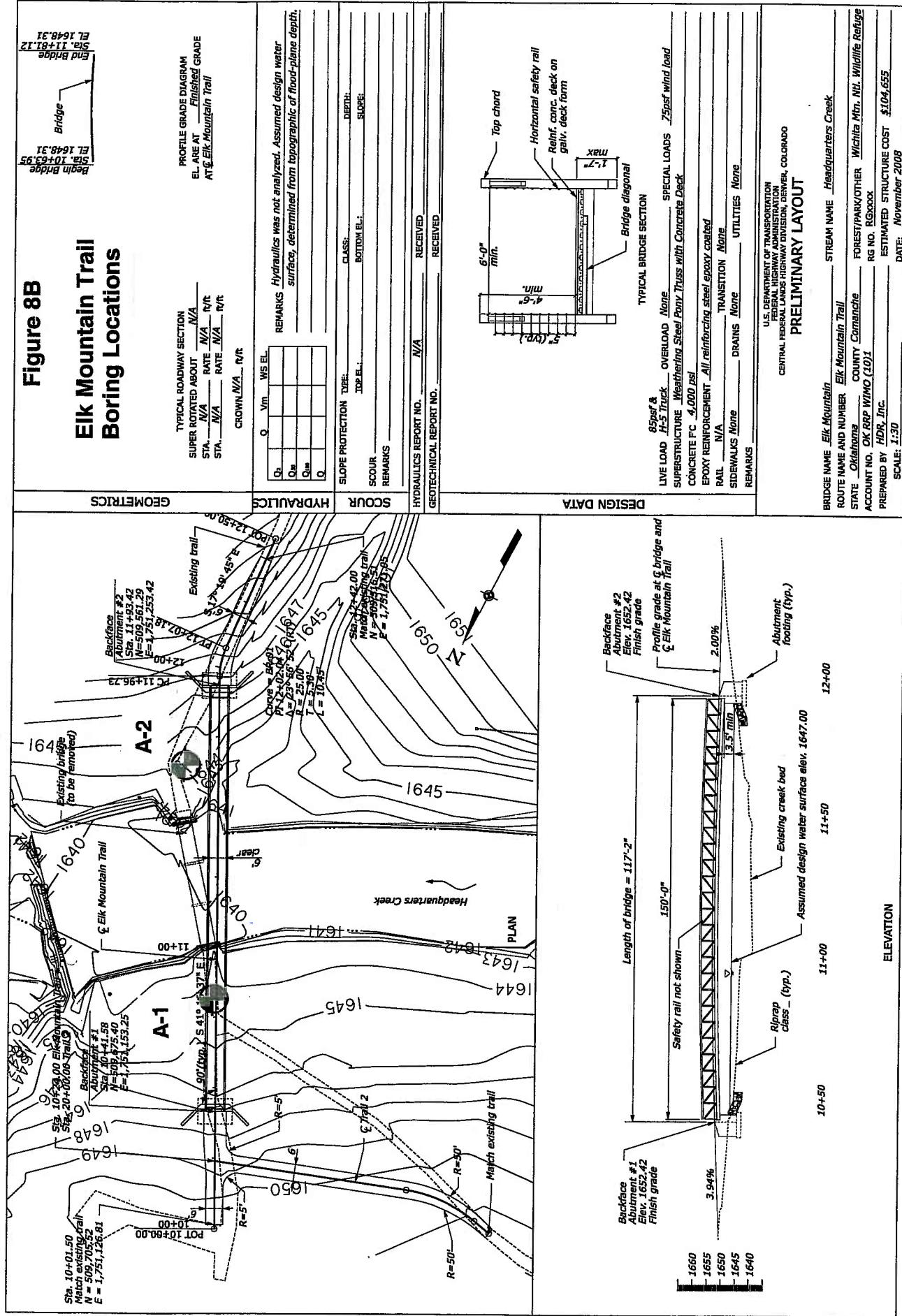
Approximate Boring Locations

Project: Wichita Mountain Wildlife Refuge

Figure Number:  
8A

**Figure 8B**

## **Elk Mountain Trail Boring Locations**



**Table 1 – Pavement Thickness Measurements**

Route	Boring Number	Approximate Station	Pavement Thickness (Inches)
11	P-2	127	12
11	P-5	201	11
10	P-10	632	6
10	P-11	658	6

Because of the uniformity of the subgrade soils, bulk soil samples were taken from a depth of one to five feet at every other boring location for the shoulder and pavement subgrade investigation. California tube samples were obtained at depths of two and five feet at every boring location. The soil samples were transported to our laboratory where they were examined and classified by the project engineer. Laboratory tests included grain size analysis, Atterberg limits, and Hveem Stabilometer (R-value) tests as well as in-place moisture and density. Subsoil encountered consists of 1 to 5 feet of medium dense to very dense gravelly sand or sandy gravel with cobbles in many locations. In many locations granite or decomposed granite bedrock was encountered at depths of 3 to 5 feet. Laboratory tests indicated that the predominant subgrade soil has AASHTO soil classification of A-2-6, with a few samples with AASHTO classifications of A-6(14) and A-4(1). R-values were measured using combined A-2-6 samples and combined A-6 samples following the Test Procedure AASHTO T190. Boring logs appear in Appendix A and complete laboratory test results are presented in Appendix B and the summary of test results for the soil samples appears in Table 2. No water was encountered in any of the pavement shoulder borings and the water level at the bridge abutment boring A-1 encountered water at 6 feet below the surface. Boring A-1 is located on the Elk Mountain Pedestrian Trail in the west portion of the park is expected to fluxuate with the water level in the adjacent creek.


**YEH & ASSOCIATES, INC**
**Summary of Laboratory Test Results**

Project No: 28 - 238

Project Name:

Date: 11/7/2008

Boring NO.	Depth (ft)	Sample Type	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			Wichita Mountain NWR			R-Value	AASHO	USCS	CLASSIFICATION
					Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	PI	pH	Water Soluble Sulfate %	% Swell (+) / Consolidation (-)	Resistivity ohm.cm	Chloride %		
P-1	0 - 5	Bulk	5.4	-	19	62	19	NV	NP	-	-	-	-	-	-	A-1-b ( 0 )	SM
P-2	1	CA	9.1	115.2	14	71	15	40	23	17	-	-	-	-	-	A-2-b ( 0 )	SC
P-3	0 - 5	Bulk	2.6	-	5	67	28	31	19	12	8.5	0.005	-	-	-	A-2-b ( 0 )	SC
P-3	1	CA	11.7	105.8	-	-	-	-	-	-	-	-1.1	-	-	-	-	-
P-4	1	CA	13.6	108.8	12	67	21	NV	NP	-	-	-	-	-	-	A-1-b ( 0 )	SM
P-5	0 - 5	Bulk	3.4	-	6	64	30	31	18	13	-	-	-	-	-	A-2-b ( 0 )	SC
P-6	4	CA	11.0	-	0	76	24	37	20	17	-	-	-	-	-	A-2-b ( 0 )	SC
P-7	0 - 5	Bulk	3.3	-	4	61	35	33	18	15	8.4	0.015	-	-	-	A-2-b ( 1 )	SC
P-7	1	CA	13.8	103.6	-	-	-	-	-	-	-	-0.4	-	-	-	-	-
P-8	1	CA	6.5	103.3	3	59	38	29	20	9	-	-	-	-	-	A-4 ( 0 )	SC
P-9	0 - 5	Bulk	5.5	-	-	70	37	13	24	-	-	-	-	-	-	A-6 ( 14 )	CL
P-10	1	CA	13.2	108.7	2	79	19	39	22	17	-	-	-	-	-	A-2-b ( 0 )	SC
P-11	0 - 5	Bulk	7.1	-	-	57	25	19	6	-	-	-	-	-	-	A-4 ( 1 )	ML - CL
P-11	1	CA	-	-	-	-	-	-	-	-	7.7	0.005	-	3086	0.0006	-	-
P-11	4	CA	-	-	-	-	-	-	-	-	7.7	0.005	-	3086	0.0006	-	-
P-12	4.0	CA	14.5	112.4	0	63	37	40	20	20	-	-	-	-	-	A-6 ( 3 )	SC
P-13	0 - 5	Bulk	2.4	-	10	59	31	29	16	13	-	-	-	-	22	A-2-b ( 0 )	SC
A-1	1.0	CA	-	-	-	-	-	-	-	-	7.1	<0.001	-	6689	0.0003	-	-
A-1	4.0	CA	-	-	-	-	-	-	-	-	7.1	<0.001	-	6689	0.0003	-	-
A-2	2.0	Bulk	13.0	-	20	59	21	NV	NP	-	-	-	-	-	-	A-1-b ( 0 )	SM

The soil test results show no significant swell or consolidation problems with the maximum consolidation reading being a consolidation of -1.1 percent.

### **Soluble Sulfate and Corrosion Susceptibility**

In order to evaluate corrosion potential, soluble sulfate, pH, chloride and resistivity measurements were made on soil samples at the bridge foundation location (Boring A-1) and also Boring P-11 to address possible roadway culvert materials.

The soluble sulfate measurements ranged from 0.001 percent to 0.015 percent. These are low soluble sulfate concentrations and are in a Class 0 level for sulfate attack based on ACI requirements. Type 1 cement or a more sulfate resistant grade of cement may be safely used in structures and culvert pipes on this project.

The resistivity measurements were 3,086 and 6,689 ohm-cm. This resistivity level is more than 3000 ohm-cm, and based on the requirements in Section 204 of FP 03. The soil conditions are minimally corrosive to metal pipes, so metal culverts such as corrugated steel pipe may be used without worry of excessive corrosion caused by native soils.

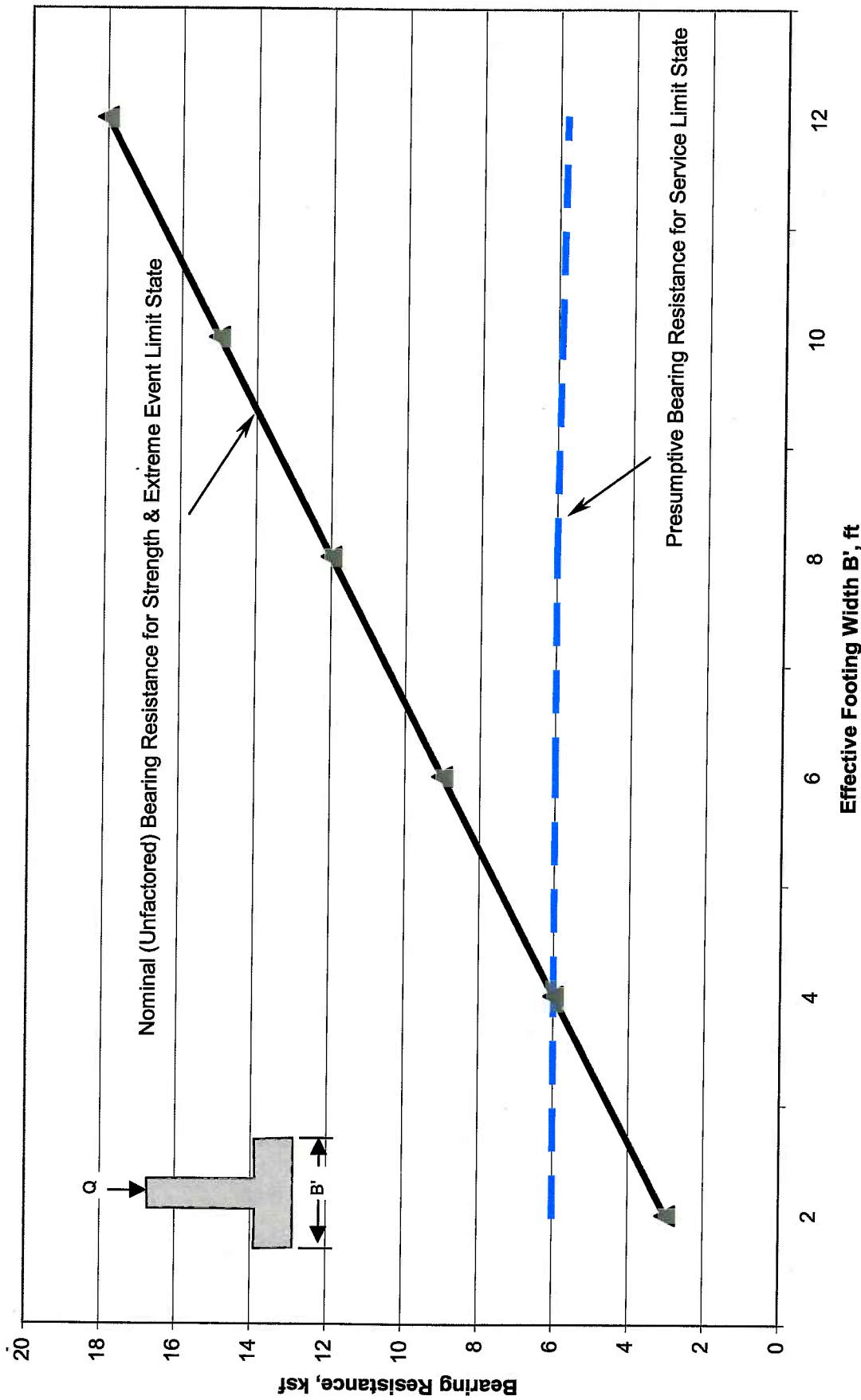
### **Bridge Foundation Recommendations**

The subsurface conditions encountered near the pedestrian bridge (see figure 8B Boring A-1 and A-2) consist of medium dense, low plasticity, angular to subangular, silty sand with occasional gravel and cobbles. Based on the results of our field exploration and laboratory testing, the proposed new pedestrian bridge may be founded on a spread footing foundation.

For a spread footing foundation with a maximum of one-inch settlement, we recommend a maximum presumptive bearing capacity (service limit state) of 6 ksf. Figure 9 shows the relationship of the nominal (unfactored) and presumptive (service) bearing resistance for different footing widths.

It should also be noted that all the calculations and recommendations are based on concentric loading, which is uniformly applied over the effective footing width, and that future water levels do not rise above the bottom of the spread footing ( $D_f = 0$ ). We also assumed that the existing soil unit weight is 125pcf with an internal friction angle of 35°. The LRFD resistance factors for each limit state are provided in the following Table 3.

### LRFD - Width vs. Resistance



**Table 3 - Resistance Factors for each Limit States**

LRFD Resistance Factors			
Limit State	Bearing	Shear Resistance to Sliding	Passive Pressure Resistance to Sliding
Strength	0.5	0.8	0.5
Service	1.0	-	-
Extreme Event	1.0	1.0	1.0

The recommended coefficient of at-rest earth pressure is 0.42 with an equivalent fluid pressure of 50 psf. The recommended coefficient of active earth pressure is 0.27 with an equivalent fluid pressure of 35 psf.

## Pavement Recommendations

### **Traffic Loading**

Present (2008) Average Annual Daily Traffic (AADT) volumes, vehicle type information, and the annual growth factor was supplied by representatives the traffic consultants, URS Engineering and Wildlife Refuge personnel. Using this information, present and calculated future volumes were used to determine the 20-year Equivalent Single Axle Loading (ESALs) for the two routes. For the design ESAL calculations, the traffic volumes were broken down as listed in Table 4 and ESAL factors for each of these vehicle types were obtained from the V1 and V2 Guidelines.

Since this project only shoulders are planned to be paved on this project, the ESAL loading for pavement thickness design was lowered based on 10% of the mainline traffic pulling onto the shoulders. The 20-year design ESAL loading after incorporating a correction factor are presented in Table 5 and the complete calculations are listed in Appendix C.

**Table 4 – ESAL Calculation Inputs**

Vehicle Type	Percent of Volume	ESAL Factor (V1 & V2)
Cars and Pickups	90	0.0004
2-axle SU (RVs)	4	0.5
3-axle trucks	1	1.5
Busses	5	0.88

**Table 5 – Design 20-year Design Life 18K ESALs**

Roadway Sections	20-Year Flexible ESALs
Route 10 Shoulder	64,027
Route 10 Mainline	640,273
Route 11 Shoulder	45,361

***Determination of Resilient Modulus ( $M_R$ ) of Subgrade for Design***

Laboratory test results measured R-values of 16 and 22 for the A-2-6 soils, and an R-value of 11 for the A-6 clay soil. For design purposes, the average R-value of 16 was used to determine the resilient modulus for this pavement design.

The following equations are from the Colorado Department of Transportation (CDOT) Pavement Design Manual, but they originally came from NCHRP Study 128, which was used in the AASHTO 1993 Pavement Design Guide. Using these equations, an R-value of 16 was used to calculate a resilient modulus of 4,334 psi.

$$S_1 = [(R-5)/11.29] + 3 \quad (\text{Eq. 2.1})$$

$$M_R = 10^{[S_1 + 18.72]/6.24} \quad (\text{Eq. 2.2})$$

Where:  $M_R$  = resilient modulus (psi)

$S_1$  = the soil support value

R = the R-value obtained from the Hveem Stabilometer (AASHTO T190)

The resilient modulus of 4,334 psi was then used as one of the inputs for the DARWin Pavement Design computer program to determine recommended pavement thickness for the various pavement options. The DARWin pavement design computer program follows the AASHTO 1993 Pavement Design Manual.

Other Structural Layer coefficients were assigned based on various treatments found in the "Guidelines for Completing the Pavement Investigation and Report (V1 and V2 Activities) CFLHD January 2005."

***Pavement Thickness Recommendations***

The pavement design computer program DARWin Version 3.1 was employed to determine the AASHTO pavement thickness designs for a full depth HACP section and a

composite pavement section using aggregate base course (ABC) and Hot Asphalt Concrete Pavement. The DARWin pavement design program follows the 1993 AASHTO Pavement Design Guidelines. The DARWin pavement design outputs are presented in Appendix D.

The parameters for the pavement designs for the HMA and Composite pavement are shown in Table 6:

**Table 6 – Flexible Pavement Design Parameters**

Initial Serviceability	4.2	Reliability Level, %	75
Terminal Serviceability	2.5	Overall Standard Deviation	0.49
Str. Layer Coeff. – Asphalt Mix	0.40	Str. Layer Coeff. – ABC	0.14
Subgrade Resilient Modulus	4,334	Minimum R-value for ABC	80

The DARWin program's output for the recommended pavement thickness designs are shown in Appendix D and summarized in Table 7.

**Table 7 – HACP Pavement Design Thickness Alternatives**

Section Description		Route 10 Thickness	Route 11 Thickness
Full Depth HACP	HACP Thickness (inches)	6.25	6.0
HACP + ABC	HACP Thickness (inches)	3.0	3.0
	ABC Thickness (inches)	9.0	9.0
HACP + ABC	HACP Thickness (inches)	3.5	3.5
	ABC Thickness (inches)	8.0	7.0
HACP + ABC + Select Borrow	HACP Thickness (inches)	2.5	2.5
	ABC Thickness (inches)	4.0	4.0
	Select Borrow (inches)	12.0	10.0

Table 8 shows the required thickness for Mainline Route 10 to be used for patching over culvert pipe replacements. We recommend the full depth HACP patch for ease of construction since a small quantity of HMA will be required at any single patch location.

**Table 8 – Route 10 HACP Mainline Patching Thickness**

Section Description		Route 10 Thickness
Full Depth HACP	HACP Thickness (inches)	9.0
HACP + ABC	HACP Thickness (inches)	7.0
	ABC Thickness (inches)	6.0

Four structurally equivalent shoulder sections are presented so that a comparison of costs could be made to help with the selection of the recommended construction alternative.

In order to compare the costs of the various alternate designs, costs were obtained for the Oklahoma DOT web page. Costs for HACP containing PG 64-22, ABC, and Embankment were obtained from 2009 projects. These materials costs were then used to compare the various pavement section alternatives presented above. Two sets of cost comparisons were calculated. The first comparison was using the Oklahoma DOT costs directly. The second comparison used inflation factors since this a FHWA project, and local contractors might inflate their bid costs because of unknowns in meeting FHWA specifications. For the inflated comparisons, the HACP cost was inflated 50% and the ABC and Select Borrow was inflated 10%. Table 9 lists the material costs used in both comparisons, and Table 10 lists the comparative cost for each alternate pavement option. Complete calculations for these alternative costs are shown in Appendix E

**Table 9 – Pavement Materials Input Costs**

Material	Oklahoma Cost Data	Inflated Cost for FHWA
HACP, Ton	\$70.00	\$105.00
ABC, Class 6, Cu. Yd.	\$42.00	\$46.20
Select Borrow, Cu. Yd.	\$25.00	\$27.50

**Table 10 – Pavement Option Costs**

Pavement Design Option	Oklahoma Cost Data, \$/Sq. Yd.		Inflated Cost Data, \$/Sq. Yd.	
	Route 10	Route 11	Route 10	Route 11
Full Depth HACP	\$24.06	\$23.10	\$36.09	\$34.65
HACP + ABC (3")	\$23.22	\$22.05	\$30.16	\$28.88
HACP + ABC (3.5")	\$22.81	\$21.64	\$30.48	\$29.20
HACP + ABC + Select Borrow	\$22.63	\$21.24	\$28.74	\$27.21

Using the Oklahoma DOT data, all of the alternate designs are within 9% and if the full depth design is eliminated, the remaining designs are within 6% in cost. Using the Oklahoma costs data directly shows that the comparative costs are probably similar within the error of the estimate.

Using the inflated data, the full depth option is approximately 25% higher than any of the other options. The three remaining options are within 7% in cost, and the 3" of HACP of ABC is only 5% to 7% above the composite design with Select Borrow and ABC.

The costs of the three composite designs are within 10% which is well within the accuracy of the estimates. We recommend the composite section using three inches of HACP with ABC. Since only two materials will need to be placed and the HACP can be placed on one lift making construction easier. Less in-place material will need to be removed to make room for the base course, and savings in construction time should help make up for the higher cost of the 3.0 inches of HACP.

#### ***Hot Asphalt Concrete Pavement Mix and Binder Recommendations***

The HACP used for the shoulder widening should be a nominal ½-inch mix with PG 64-22 Performance Graded Binder. The Superpave Grading E mix as referenced in FP-03 is recommended. Oklahoma Department of Transportation uses the Superpave mix design system, and a 75 gyration mix using nominal ½ inch aggregate is recommended.

The binder for this project should be a performance graded binder meeting the requirements for PG 64-22.

The LTPPBind program was used to determine the binder grade for this area, and based on the weather information from Lawton, Oklahoma a grade of PG 64-16 would meet

requirements for this area. However, Oklahoma DOT does not specify that grade and instead recommends PG 64-22. Since PG 64-22 will be readily available in Oklahoma, and meets or exceeds the specification requirements for the PG 64-16, we recommend that PG 64-22 Binder be used.

The aggregate base course should receive a prime coat of either cutback asphalt MC-70 at a rate of 0.25 gallons per square yard, or an emulsion blended as a penetrating prime at a rate of 0.33 gallons per square yard. If an emulsion such as CSS-1 is used for prime coat, it should be disked into the top 2-3 inches of base course and recompacted prior to placement of the new HCAP.

#### ***Pavement Subgrade Preparation***

The asphalt pavement design thicknesses were calculated using the Resilient Modulus calculated from R-values ranging from 10 to 22. Fill material imported for embankment on this project should be required to have a minimum R-value of 25 if used in the top two feet below the pavement.

Prior to placement of base course or other fill material, the in-place soils will require a minimum of 6 inches of scarification and recompaction within 2 percent of optimum moisture content. The in-place soils should be compacted to at least 95 percent modified Proctor maximum dry density (AASHTO T180). Aggregate base course should meet the FP-03 gradation requirements and have a minimum R-value of 80 when tested in accordance with AASHTO Procedure T-190.

The pavement subgrade should be proof rolled with a heavily loaded pneumatic-tire vehicle. Areas which deform more than 0.5 inch under heavy wheel loads should be removed and replaced then recompacted to achieve a stable subgrade prior to paving. We also recommend proof rolling of the subbase prior to placement of the aggregate base course. Proof rolling and subgrade compaction tests should be observed and reviewed by a representative of the geotechnical engineer prior to asphalt paving.

#### ***Drainage Considerations***

The collection and diversion of surface drainage away from paved areas is critical to the satisfactory performance of the pavement. Proper drainage design should include prevention of ponding of water on or immediately adjacent to pavement areas. If any landscape sprinkler heads and lines are installed adjacent to pavement areas they should be frequently checked for leaks and maintained in good working order. Over-spray from sprinklers should be

minimized. Concentrated runoff should be avoided in areas susceptible to erosion and slope instability.

### Limitations

This report has been prepared in accordance with generally accepted soil engineering practices in this area for use by the client for design purposes. The conclusions and recommendations submitted in this report are based upon the data obtained from the soil samples and traffic information provided by URS and NWR personnel. The nature and extent of subsurface variations across the site may not become evident until excavation is performed. If during construction, fill, soil, rock or water conditions appear to be different from those described herein, this office should be notified to reevaluate the geotechnical recommendations.

Yeh and Associates, Inc.

Prepared by:



Sam Yu, E.I.T.  
Project Engineer

Reviewed by:



Robert F. LaForce, P.E.  
Senior Materials Manager

**APPENDIX A**

---

**BORING LOGS**



**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: P 1

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1387.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 491,331.2 E: 1,778,487.6

Logged By: T. Hansen

Ground Water Notes:

Final By: T. Hansen

Depth	Dry
Date	10/14/08
Time	-

Inclination: Vertical

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
					RQD	Blows per 6 in			
1385								0.0 - 0.3 ft. Topsoil Prairie Grass.  0.3 - 3.0 ft. silty SAND with gravel, reddish brown, no to low plasticity, dry to moist, very dense, angular to subangular.	MC= 5.4 % #200= 19 % LL= NV PL= NP PI= NP AASHTO: A-1-b (0) USCS: SM
					26/40	66			
5								3.0 - 5.0 ft. GRANITE, reddish brown - dark brown, decomposed to slightly weathered, very hard, low plasticity, dry.	
					50:3"	50:3"		Bottom of Hole at 5.0 ft.	
10									
1380									



**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: P 2

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

#### Drilling Method: Solid-Stem Auger

**Drill Bit:**

**Ground Elevation:** 1419.0 ft

Drill: GME 55

## Casing:

**Location:**

#### Driller: Back Edge

#### **Weather:**

Coordinates: N: 493,738.9 E: 1,778,987.9

Logged By: T. Hansen

Ground Water Notes:					
Depth	Dry	-	-	-	-
Date	10/14/08	-	-	-	-
Time	-	-	-	-	-



# **YEH AND ASSOCIATES, INC.**

GEOTECHNICAL ENGINEERING CONSULTANTS

GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: P 3

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

#### Drilling Method: Solid-Stem Auger

**Drill Bit:**

Ground Elevation: 1443.0 ft

Drill: GMF 55

### Casing:

### Location:

#### Driller: Rock Edge

Weather.

Coordinates. N. 496,232.7 E. 1,779,293.9

Logged By: T Hansen

## Ground Water Notes:

Depth	±	Dry
Date		10/14/08
Time		

## Material Description

## Field Notes and Lab Tests

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
					Blows per 6 in	N			
1440	5				17/48	65		0.0 - 0.3 ft. Topsoil Prairie Grass. 0.3 - 3.0 ft. silty SAND with gravel and cobbles, reddish brown, no to low plasticity, dry, very dense, angular to subangular.	MC= 2.6 % #200= 28 % LL= 31 PL= 19 PI= 12 pH= 8.5 S= 0.005 % R-Value= 16 AASHTO: A-2-6 (0) USCS: SC MC= 11.7 % DD= 105.8 pcf S/C= -1.1 %
1435	10				50:0"	50:0"		3.0 - 5.0 ft. GRANITE, reddish brown, decomposed to fresh, very hard, no plasticity, dry.	
								Bottom of Hole at 5.0 ft.	



**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **P 4**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1472.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 498,862.8 E: 1,779,718.4

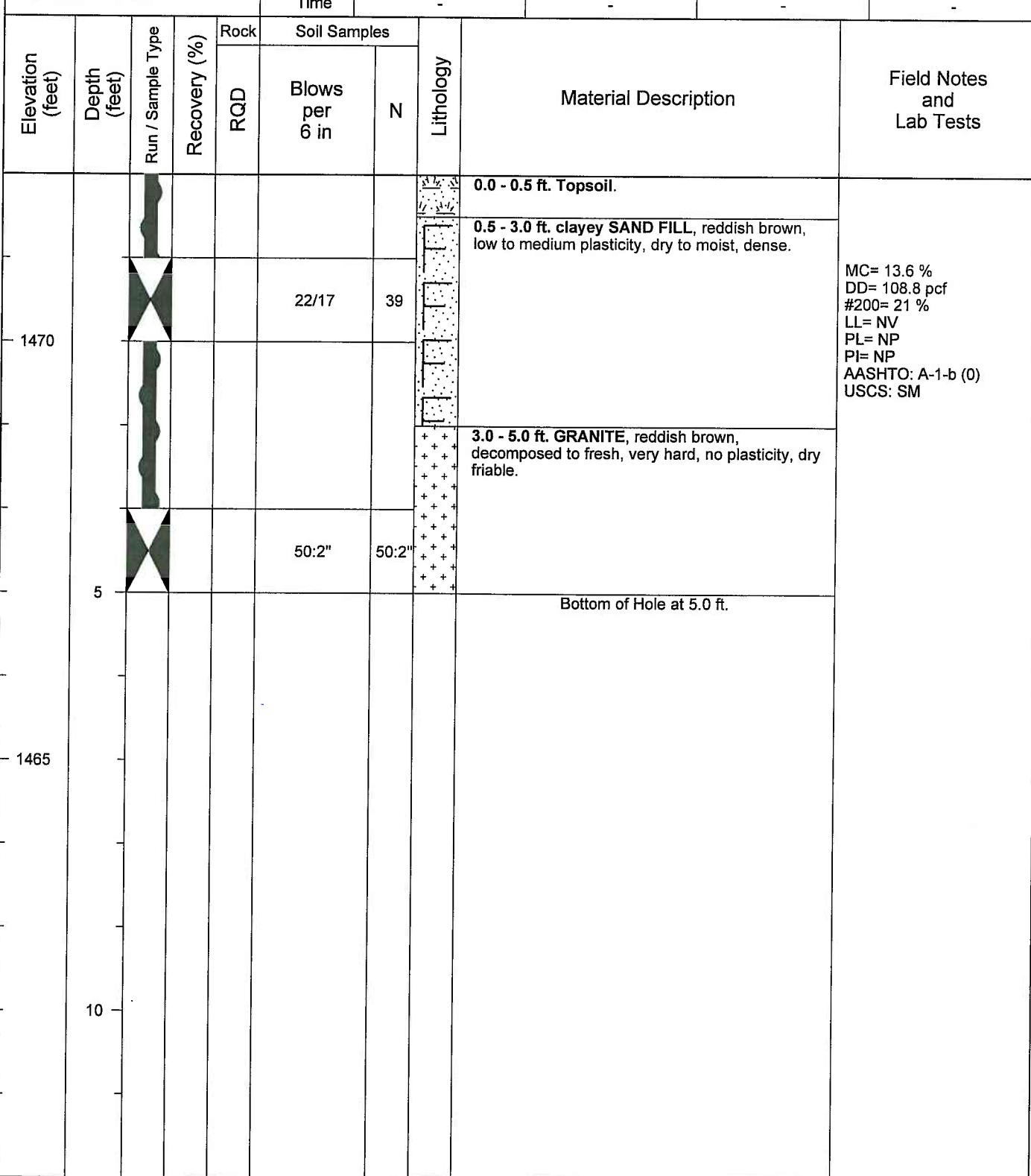
Logged By: T. Hansen

**Ground Water Notes:**

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **P 5**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1486.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 501,015.4 E: 1,779,635.5

Logged By: T. Hansen

**Ground Water Notes:**

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock RQD	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
					Blows per 6 in	N			
1485								0.0 - 0.9 ft. Asphalt Pavement.	
								0.9 - 3.0 ft. clayey SAND FILL, black - dark brown, low to medium plasticity, moist to moist, medium dense.	
								3.0 - 5.0 ft. GRANITE, reddish brown, decomposed to slightly weathered, very hard, low to medium plasticity, moist, weathered bedrock.	
								Bottom of Hole at 5.0 ft.	
1480									
10									
1475									



**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **P 6**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1497.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 501,393.2 E: 1,782,273.5

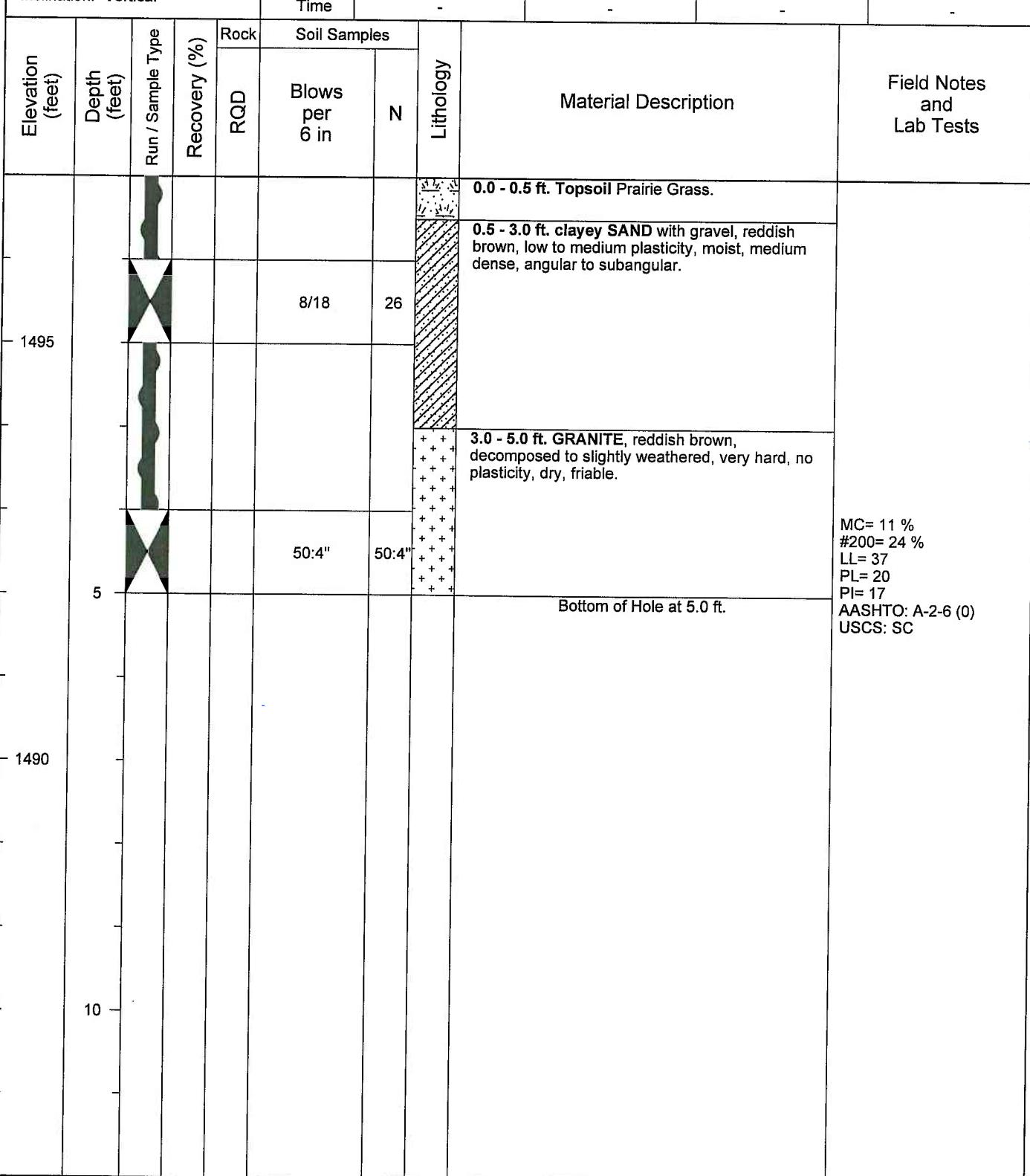
Logged By: T. Hansen

**Ground Water Notes:**

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238

Boring: P 7

Date:

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1513.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 502,376.4 E: 1,784,580.1

Logged By: T. Hansen

Ground Water Notes:

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
					RQD	Blows per 6 in			
1510								0.0 - 0.3 ft. Topsoil Prairie Grass. 0.3 - 2.5 ft. silty SAND with gravel, reddish brown, no to low plasticity, dry, medium dense.	MC= 3.3 % #200= 35 % LL= 33 PL= 18 PI= 15 pH= 8.4 S= 0.015 % R-Value= 16 AASHTO: A-2-6 (1) USCS: SC MC= 13.8 % DD= 103.6 pcf S/C= -0.4 %
					13/11	24			
5					50:1"	50:1"		2.5 - 5.0 ft. GRANITE, reddish brown, decomposed to fresh, very hard, no to low plasticity, moist.	
10								Bottom of Hole at 5.0 ft.	
1505									



**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **P 8**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1552.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 504,086.0 E: 1,786,689.7

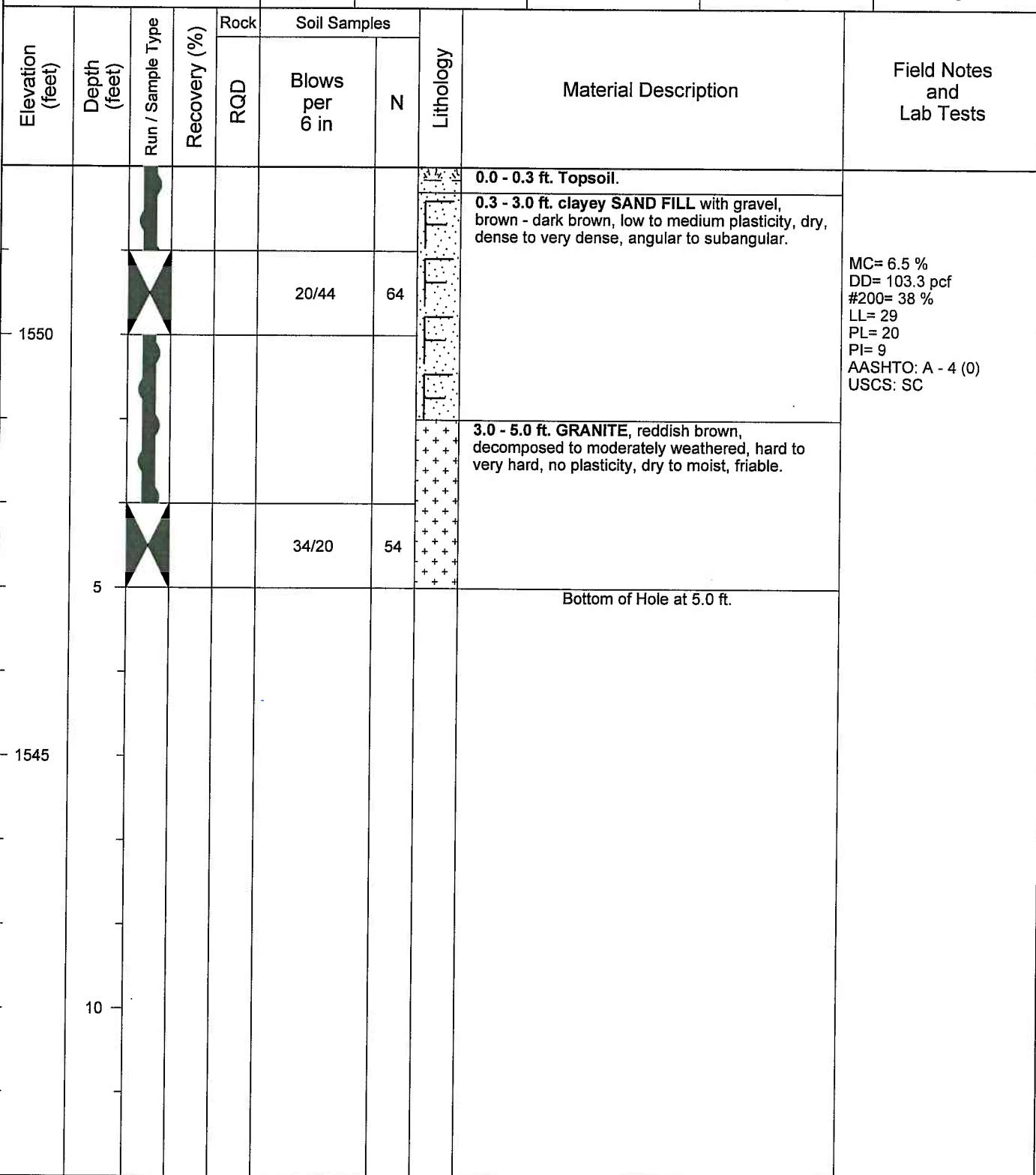
Logged By: T. Hansen

**Ground Water Notes:**

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **P 9**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1556.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 506,164.5 E: 1,788,081.5

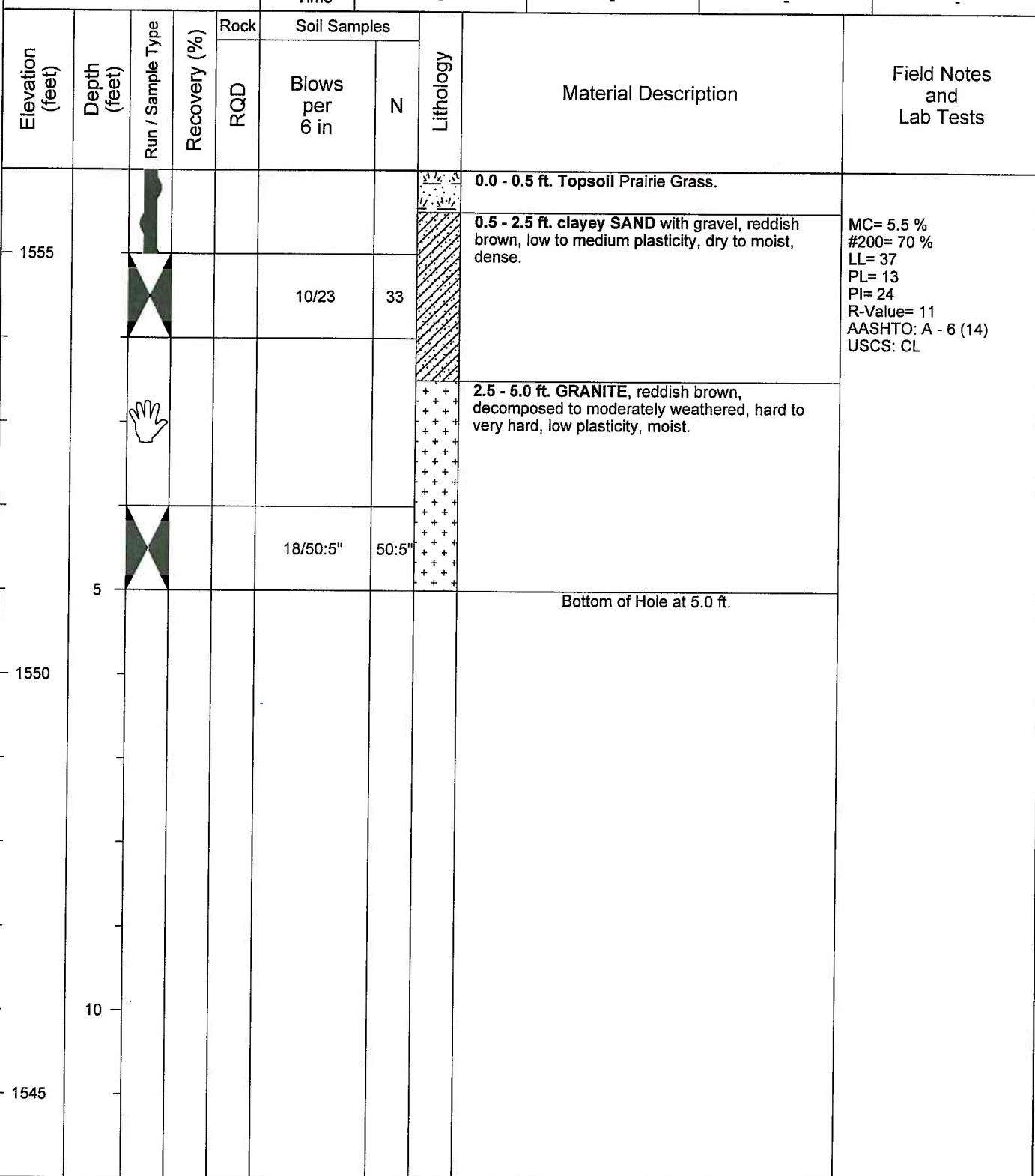
Logged By: T. Hansen

**Ground Water Notes:**

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **P 10**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1603.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 507,925.7 E: 1,789,997.9

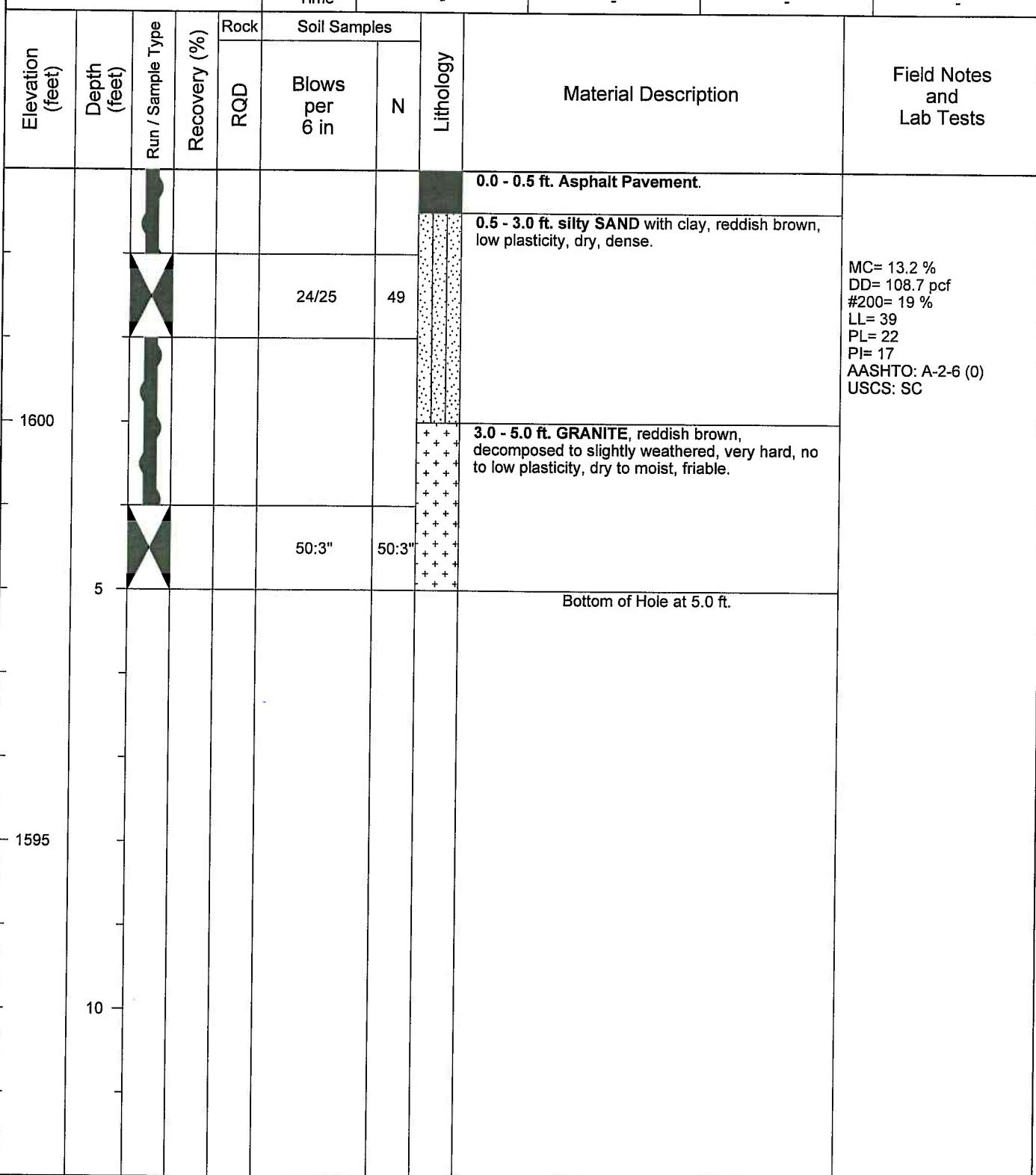
Logged By: T. Hansen

Ground Water Notes:

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238

Boring: **P 11**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1648.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 509,994.5 E: 1,791,619.9

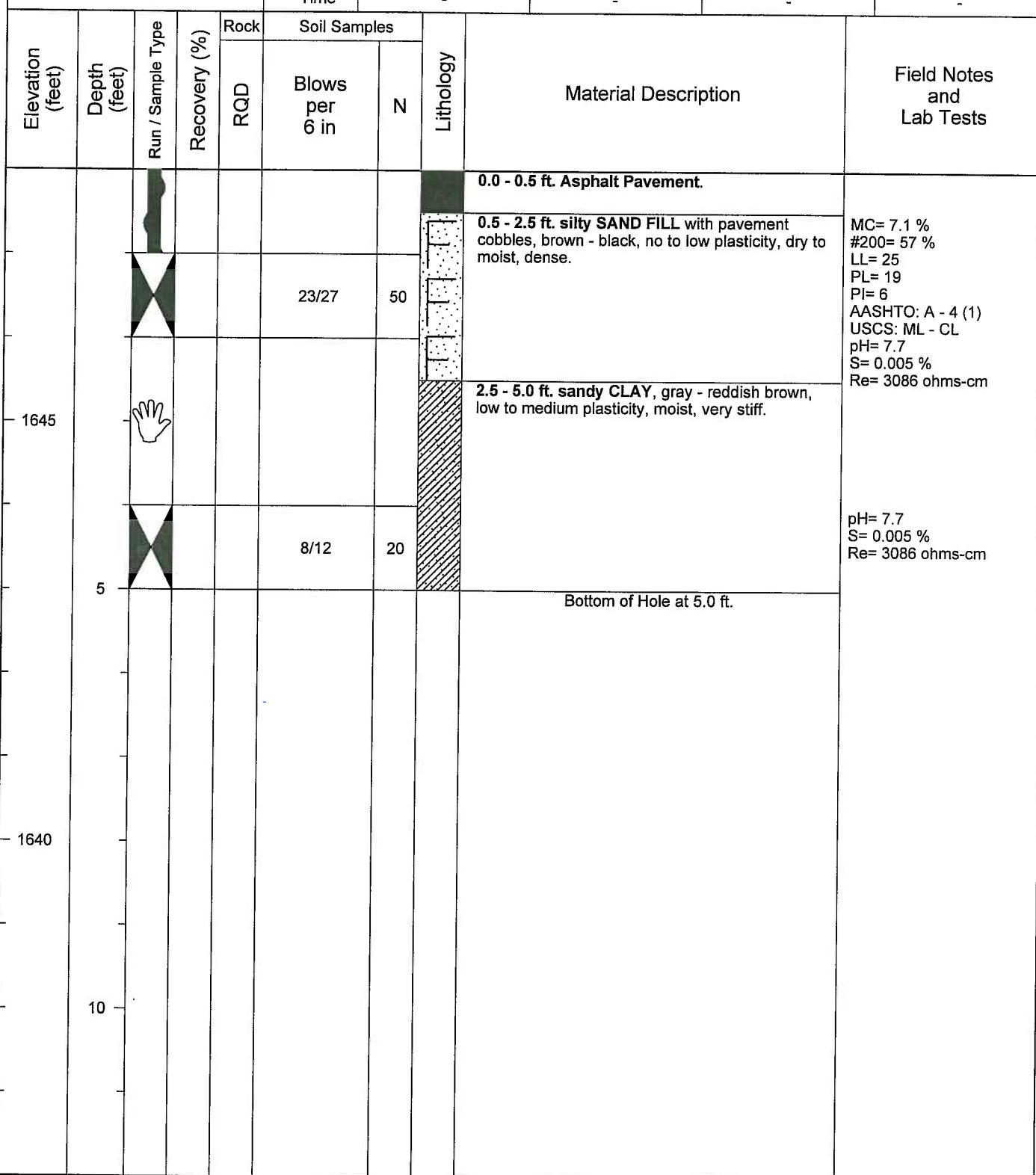
Logged By: T. Hansen

**Ground Water Notes:**

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: P 12

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 5.0 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1645.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 510,865.4 E: 1,793,159.4

Logged By: T. Hansen

Ground Water Notes:

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples		Lithology	Material Description	Field Notes and Lab Tests
					RQD	Blows per 6 in			
								0.0 - 0.5 ft. Topsoil Prairie Grass.	
								0.5 - 3.0 ft. silty SAND with gravel and cobbles, reddish brown, no plasticity, dry to moist, dense.	
								3.0 - 5.0 ft. GRANITE, reddish brown, decomposed to moderately weathered, hard, no to low plasticity, moist, friable.	
1640	5				21/18	39			
1635	10				50:6"	50:6"		Bottom of Hole at 5.0 ft.	MC= 14.5 % DD= 112.4 pcf #200= 37 % LL= 40 PL= 20 PI= 20 AASHTO: A - 6 (3) USCS: SC



# **YEH AND ASSOCIATES, INC.**

GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: P 13

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 50 ft

#### Drilling Method: Solid-Stem Auger

## **Drill Bit:**

Ground Elevation: 1631.0 ft

Drill: CME 55

### Casing:

**Location:**

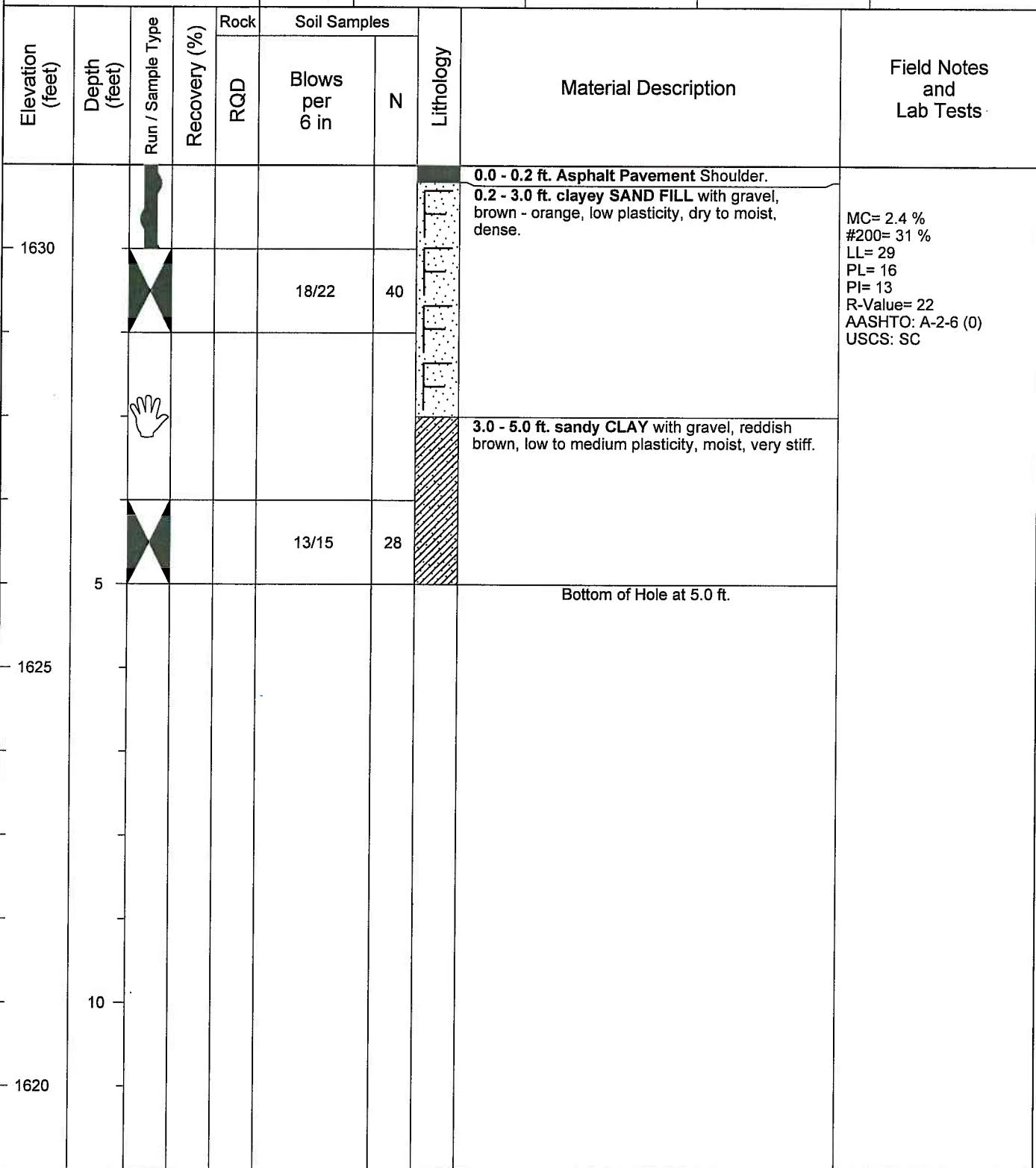
#### Driller: Back Edge

## Weather:

Coordinates: N: 509,804.3 E: 1,794,935.1

Logged By: T. Hansen

Ground Water Notes:					
Depth	Y	Dry	-	-	-
Date		10/14/08	-	-	-
Time		-	-	-	-





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **A 1**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 7.5 ft

Drilling Method: Solid-Stem Auger

Drill Bit:

Ground Elevation: 1644.0 ft

Drill: CME 55

Casing:

Location:

Driller: Rock Edge

Weather:

Coordinates: N: 491,111.0 E: 1,711,111.0

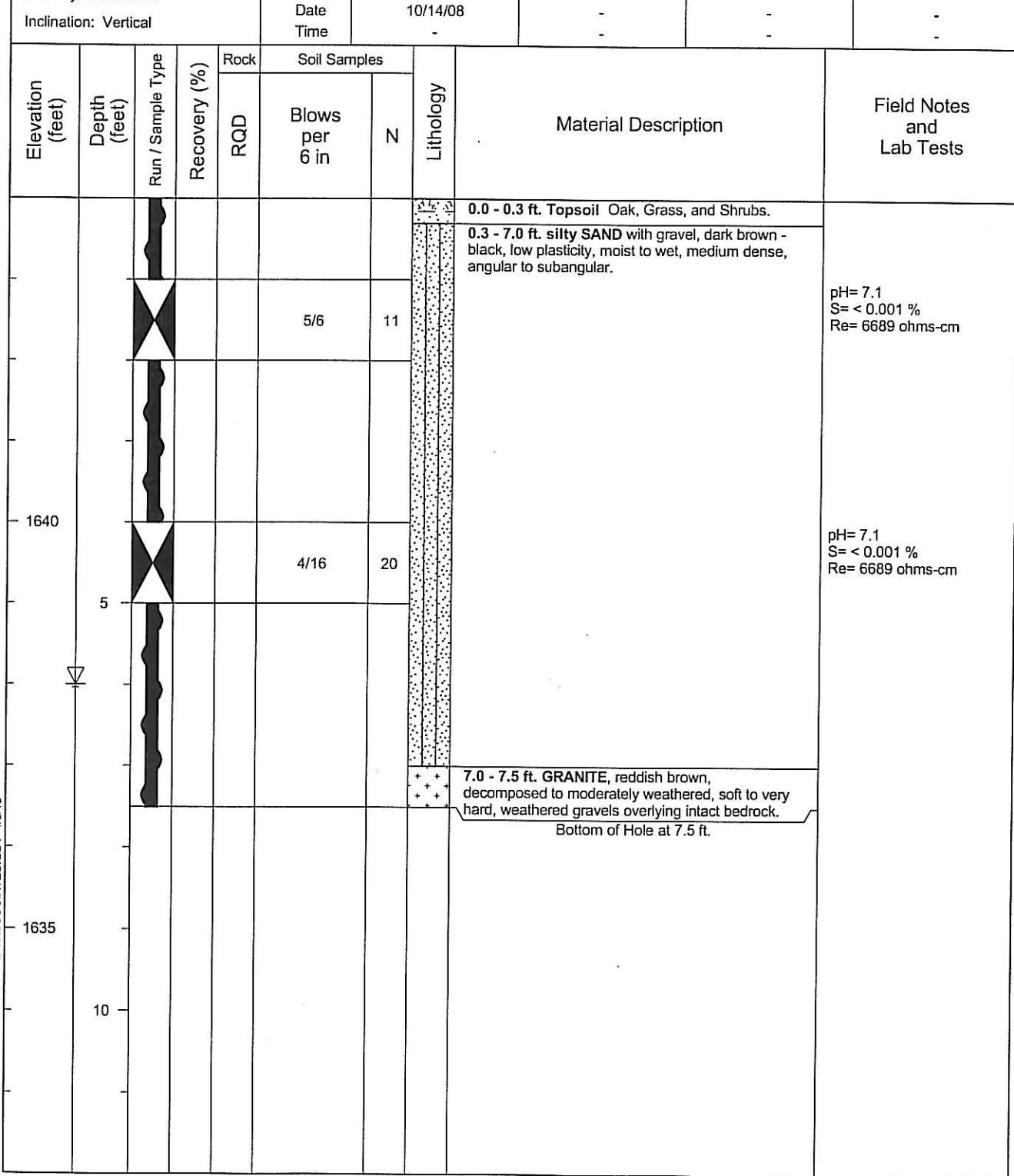
Logged By: T. Hansen

Ground Water Notes:

Final By: T. Hansen

Depth	6.0 ft	-	-	-
Date	10/14/08	-	-	-
Time	-	-	-	-

Inclination: Vertical





**YEH AND ASSOCIATES, INC.**  
GEOTECHNICAL ENGINEERING CONSULTANTS

Project: Wichita Mountain NWR

Project Number: 28-238 Date:

Boring: **A 2**

Sheet 1 of 1

Boring Began: 10/14/2008

Completed: 10/14/2008

Total Depth: 2.0 ft

Drilling Method: Hand Auger

Drill Bit:

Ground Elevation: 1644.5 ft

Drill:

Casing:

Location:

Driller:

Weather:

Coordinates: N: 492,222.0 E: 1,722,222.0

Logged By: T. Hansen

Ground Water Notes:

Final By: T. Hansen

Depth	Dry	-	-	-
Date	10/14/08	-	-	-
Time		-	-	-

Inclination: Vertical

Elevation (feet)	Depth (feet)	Run / Sample Type	Recovery (%)	Rock	Soil Samples				Material Description	Field Notes and Lab Tests
					RQD	Blows per 6 in	N	Lithology		
									0.0 - 0.3 ft. Trail pathway.	
									0.3 - 2.0 ft. silty SAND with gravel, dark brown - black, low plasticity, moist to wet, medium dense, angular to subangular, refusal on cobbles.	
									Bottom of Hole at 2.0 ft.	
1640	5									MC= 13 % #200= 21 % LL= NV PL= NP PI= NP AASHTO: A-1-b (0) USCS: SM
1635	10									

**APPENDIX B**

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**LABORATORY TEST RESULTS**



**YEH & ASSOCIATES, INC**

## Summary of Laboratory Test Results

Project No: 28 - 238

Project Name:

Wichita Mountain NWR

Date: 11/7/2008

Boring No.	Depth (ft)	Sample Type	Natural Moisture Content (%)	Natural Dry Density (pcf)	Gradation			Atterberg			Water Soluble Sulfate %	% Swell (+) / Consolidation (-)	Resistivity ohm.cm	Chloride %	R-Value	CLASSIFICATION		
					Gravel > #4 (%)	Sand (%)	Fines < #200 (%)	LL	PL	pH						AASHTO	USCS	
P - 1	0 - 5	Bulk	5.4	-	19	62	19	NV	NP	-	-	-	-	-	-	A-1-b ( 0 )	SM	
P - 2	1	CA	9.1	115.2	14	71	15	40	23	17	-	-	-	-	-	A-2-6 ( 0 )	SC	
P - 3	0 - 5	Bulk	2.6	-	5	67	28	31	19	12	8.5	0.005	-	-	-	16	A-2-6 ( 0 )	SC
P - 3	1	CA	11.7	105.8	-	-	-	-	-	-	-	-1.1	-	-	-	-	-	
P - 4	1	CA	13.6	108.8	12	67	21	NV	NP	-	-	-	-	-	-	A-1-b ( 0 )	SM	
P - 5	0 - 5	Bulk	3.4	-	6	64	30	31	18	13	-	-	-	-	-	16	A-2-6 ( 0 )	SC
P - 6	4	CA	11.0	-	0	76	24	37	20	17	-	-	-	-	-	-	A-2-6 ( 0 )	SC
P - 7	0 - 5	Bulk	3.3	-	4	61	35	33	18	15	8.4	0.015	-	-	-	16	A-2-6 ( 1 )	SC
P - 7	1	CA	13.8	103.6	-	-	-	-	-	-	-	-0.4	-	-	-	-	-	
P - 8	1	CA	6.5	103.3	3	59	38	29	20	9	-	-	-	-	-	A-4 ( 0 )	SC	
P - 9	0 - 5	Bulk	5.5	-	-	70	37	13	24	-	-	-	-	-	-	11	A-6 ( 14 )	CL
P - 10	1	CA	13.2	108.7	2	79	19	39	22	17	-	-	-	-	-	A-2-6 ( 0 )	SC	
P - 11	0 - 5	Bulk	7.1	-	-	57	25	19	6	-	-	-	-	-	-	A-4 ( 1 )	ML - CL	
P - 11	1	CA	-	-	-	-	-	-	-	-	7.7	0.005	-	3086	0.0006	-	-	
P - 11	4	CA	-	-	-	-	-	-	-	-	7.7	0.005	-	3086	0.0006	-	-	
P - 12	4	CA	14.5	112.4	0	63	37	40	20	-	-	-	-	-	-	A-6 ( 3 )	SC	



YEH & ASSOCIATES, INC

## Summary of Laboratory Test Results

Project No:

Project Name:

Wichita Mountain NWR

11/7/2008

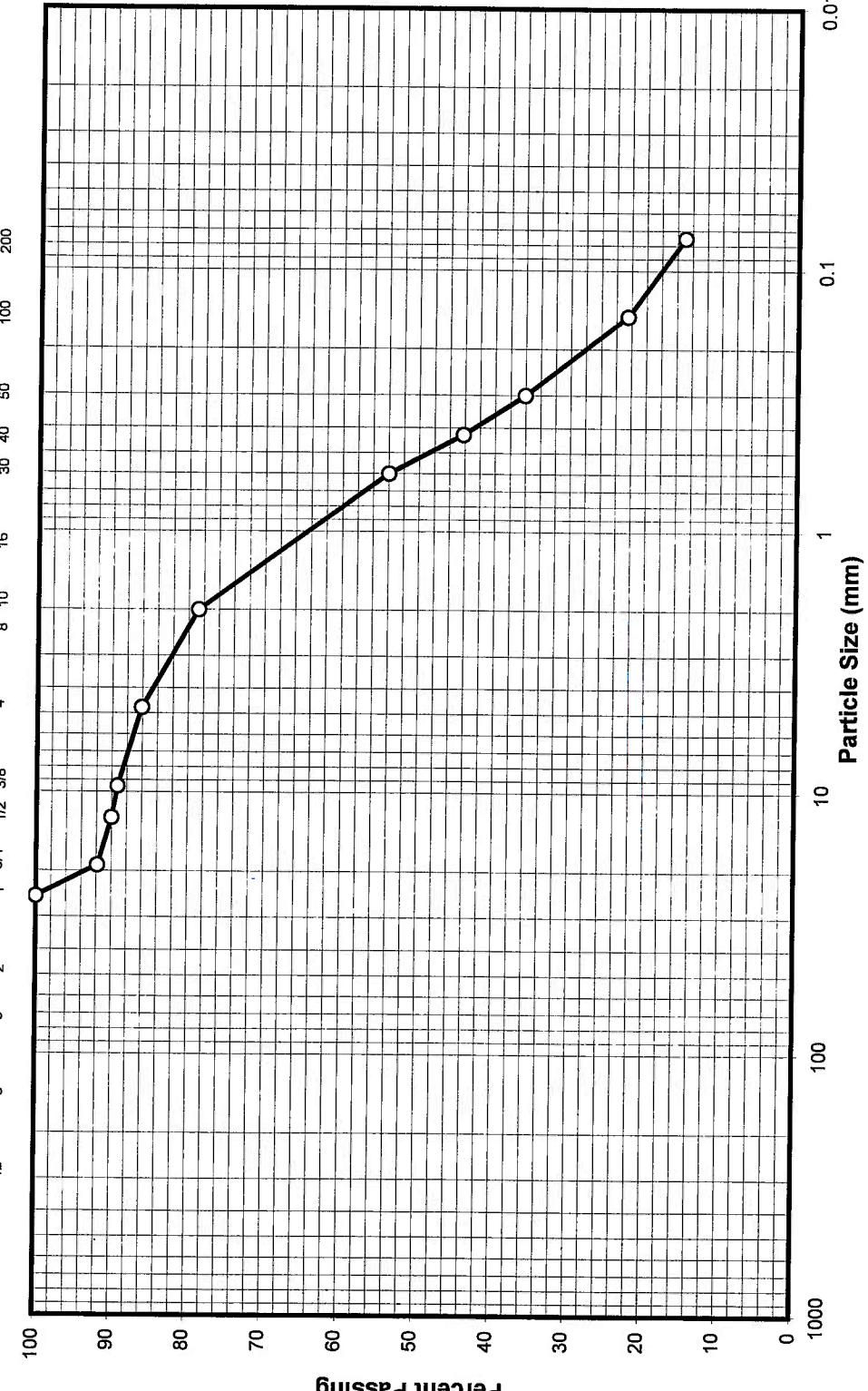
Date:

Sieve Analysis						Hydrometer Analysis	
Sieve Opening in Inches			U.S. Standard Sieves			Size of Particles in mm	
12"	6"	3"	2"	1"	3/4"	1/2"	3/8"
4	8	10	16	30	40	50	100
100	90	80	70	60	50	40	30
0	10	20	30	40	50	100	200



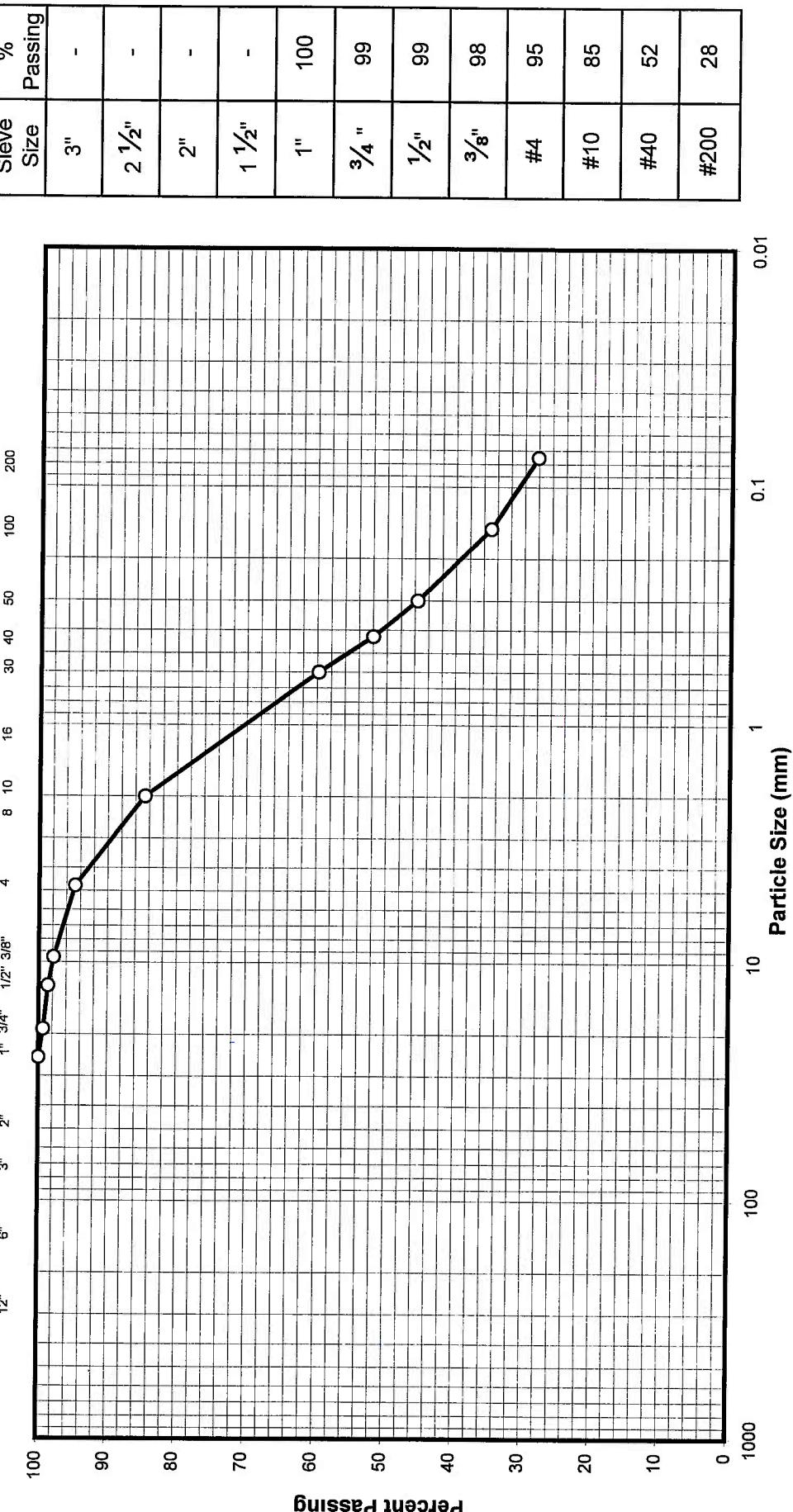
Yeh & Associates, Inc.			
Geotechnical Engineering Consultants			
SIEVE ANALYSIS			
Drawn By:	MA	Project No.:	28 - 238
Checked By:	SY	Figure No.:	-
Date:	11/07/08		
Sample Description:	SM / A - 1-b (0 )		

Sieve Analysis							Hydrometer Analysis	
				U.S. Standard Sieves				
Sieve Opening in Inches	12"	6"	3"	2"	1"	3/4"	1/2"	3/8"
	100	90	80	70	60	50	40	30

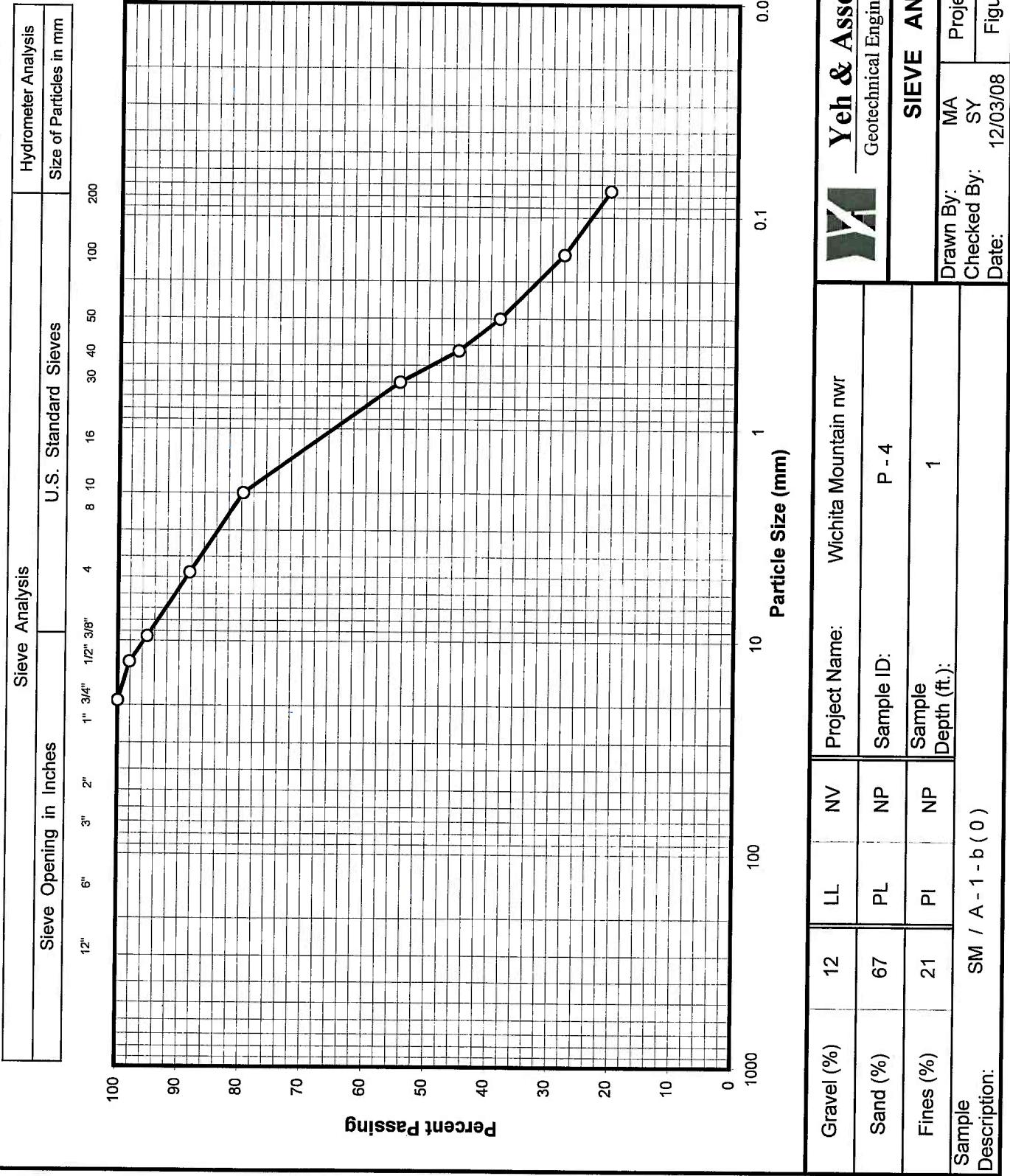


<b>Gravel (%)</b>	14	LL	40	Project Name:	Wichita Mountain nwr	<b>Yeh &amp; Associates, Inc.</b>		
				Sample ID:	P - 2			
<b>Sand (%)</b>	71	PL	23	Sample	1	<b>Geotechnical Engineering Consultants</b>		
				Depth (ft.):				
<b>Fines (%)</b>	15	PI	17	Drawn By:	MA	Project No.:		
				Checked By:	SY	Figure No.:		
<b>Sample Description:</b>	SC / A - 2 - 6 (0)				Date: 12/03/08	28 - 238		
					Figure No.:	-		

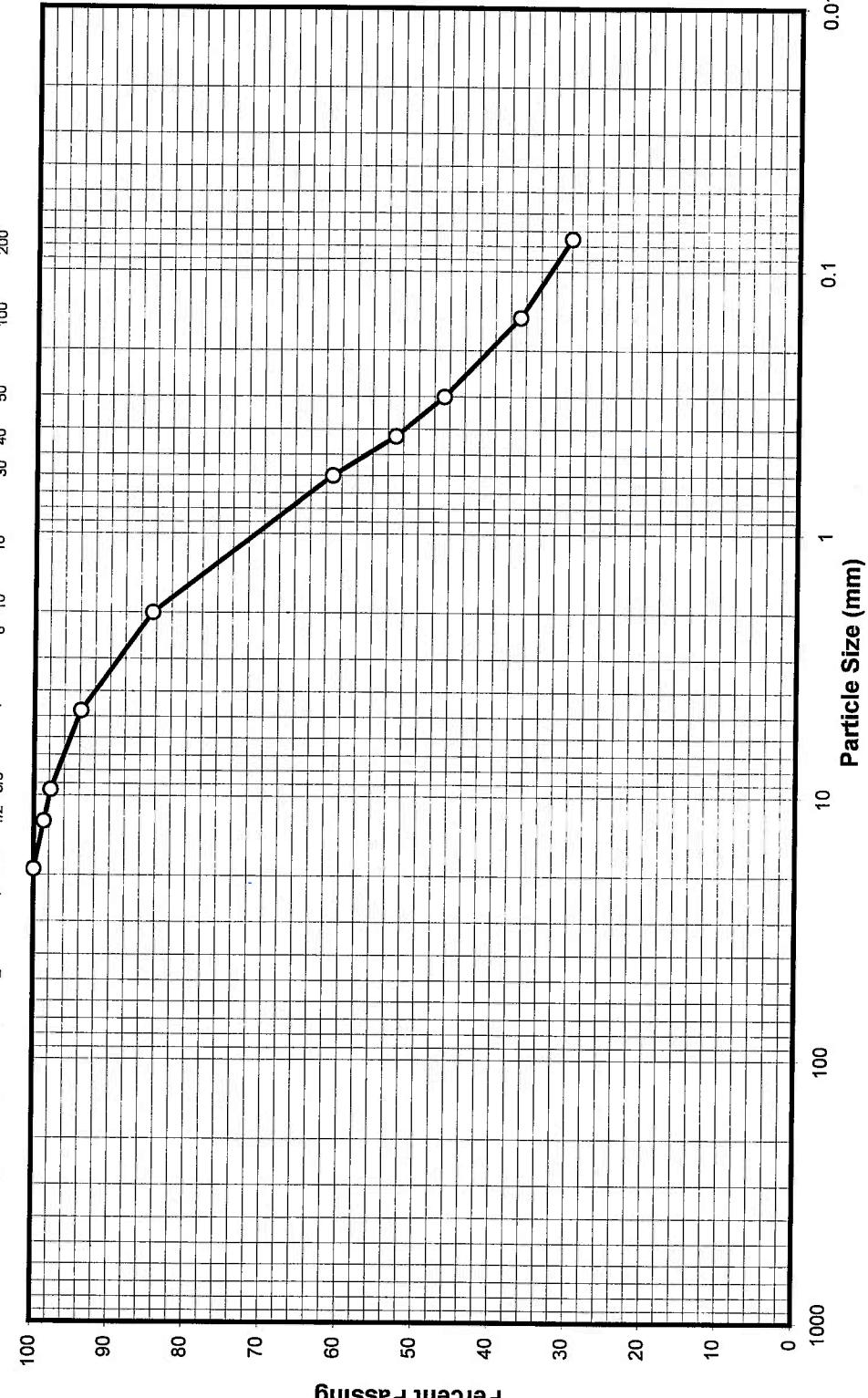
Sieve Analysis			Hydrometer Analysis		
Sieve Opening in Inches	U.S. Standard Sieves	Size of Particles in mm			
12"					



Gravel (%)			5	LL	31	Project Name:	Wichita Mountain nwr	Yeh & Associates, Inc.	
Sand (%)			67	PL	19	Sample ID:	P - 3	Geotechnical Engineering Consultants	
Fines (%)			28	PI	12	Sample Depth (ft.):	0 - 5	SIEVE ANALYSIS	
Sample Description:	SC / A - 2 - 6 (0)					Drawn By:	MA	Project No.:	28 - 238
						Checked By:	SY	Figure No.:	-
						Date:	11/07/08		

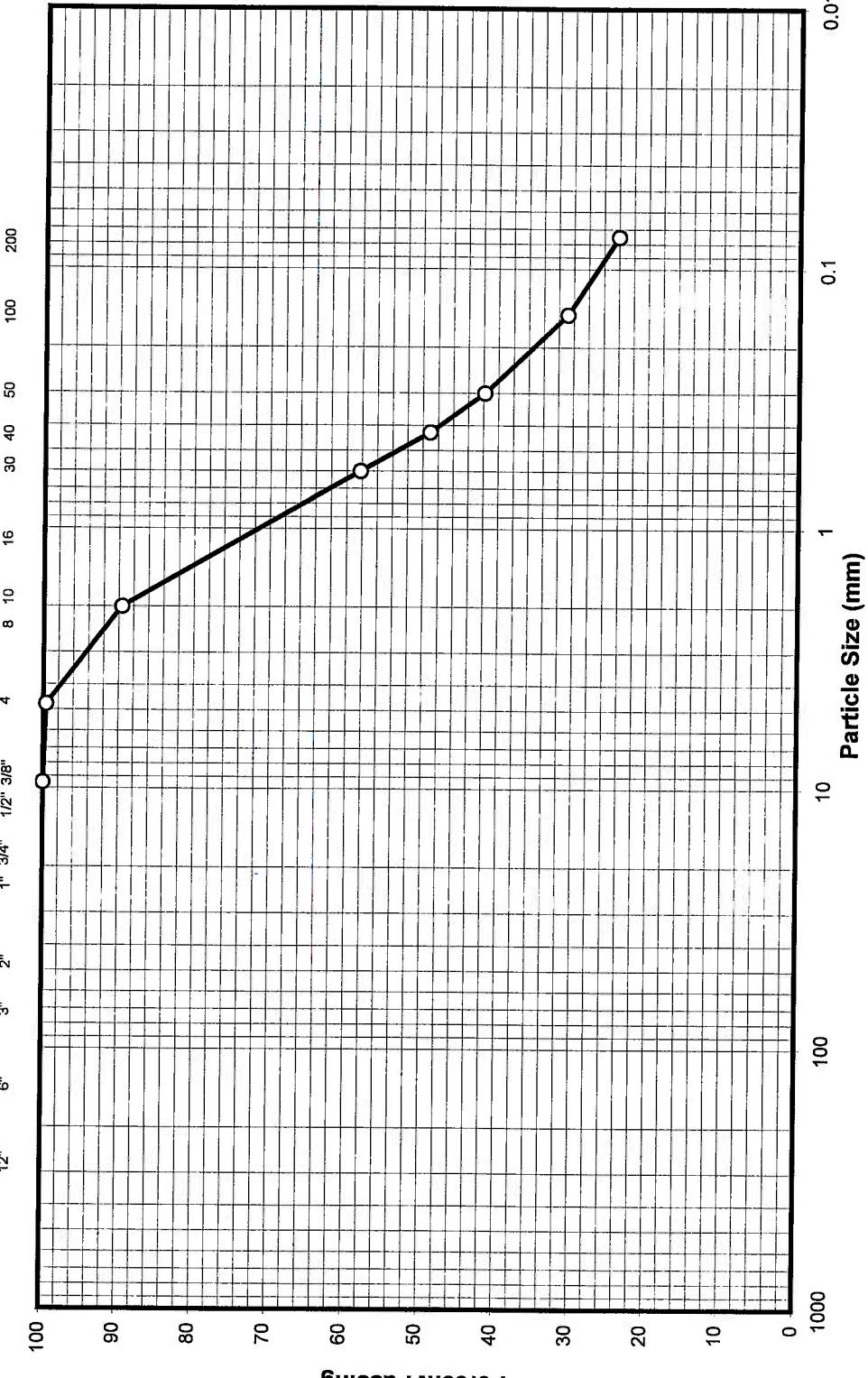


Sieve Analysis						Hydrometer Analysis	
Sieve Opening in Inches			U.S. Standard Sieves			Size of Particles in mm	
12"	6"	3"	2"	1"	3/4"	1/2"	3/8"
100							



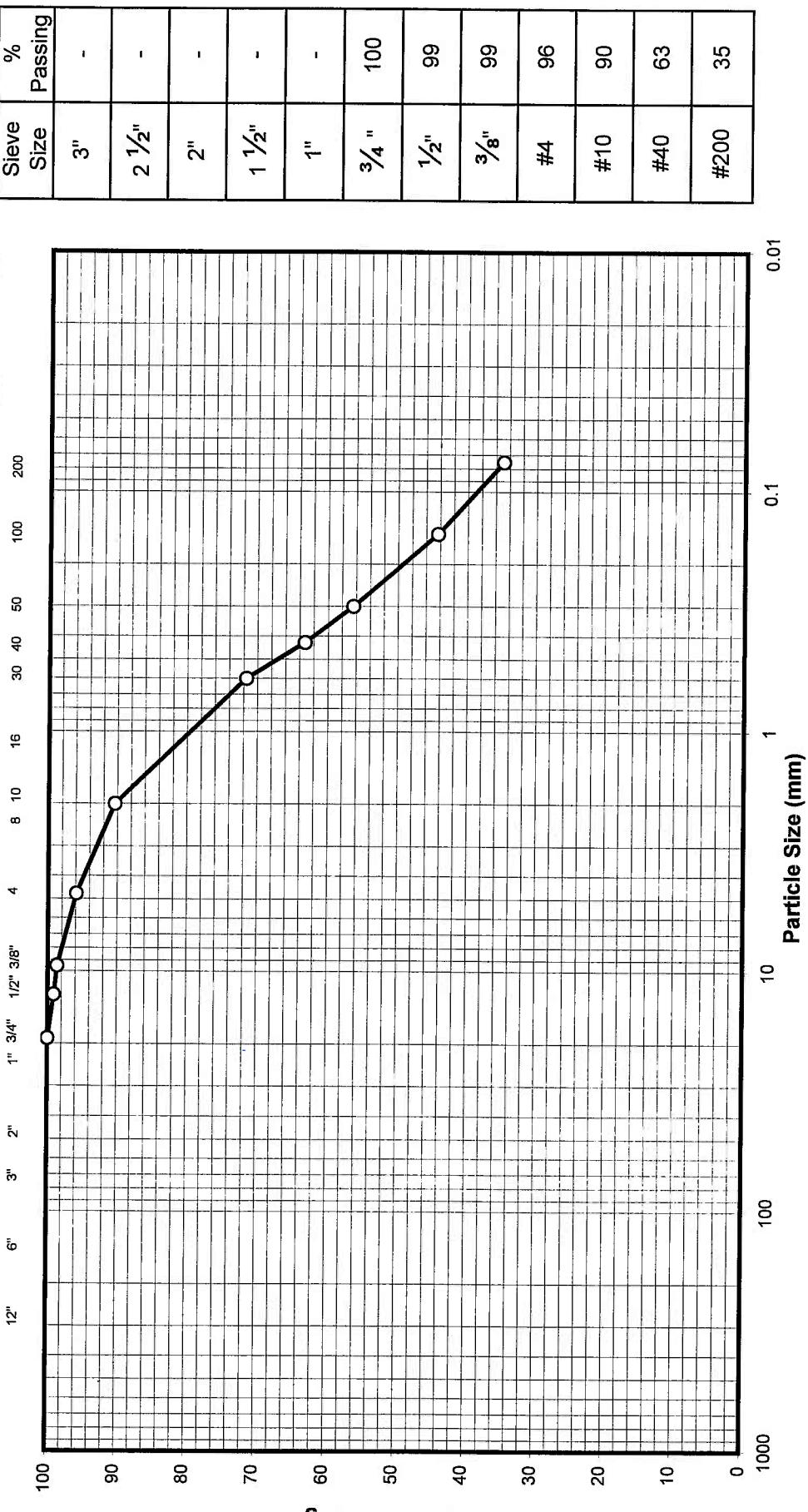
Yeh & Associates, Inc.			
Geotechnical Engineering Consultants			
SIEVE ANALYSIS			
Drawn By:	MA	Project No.:	28 - 238
Checked By:	SY	Figure No.:	-
Date:	11/07/08		
Sample Description:	SC / A - 2 - 6 (0)		

Sieve Analysis						Hydrometer Analysis	
						Size of Particles in mm	
U.S. Standard Sieves							
Sieve Opening in Inches	12"	6"	3"	2"	1"	3/4"	1/2"
12"	100						
6"		100					
3"			100				
2"				100			
1"					100		
3/4"						100	
1/2"							100
#4							
#10							
#40							
#200							



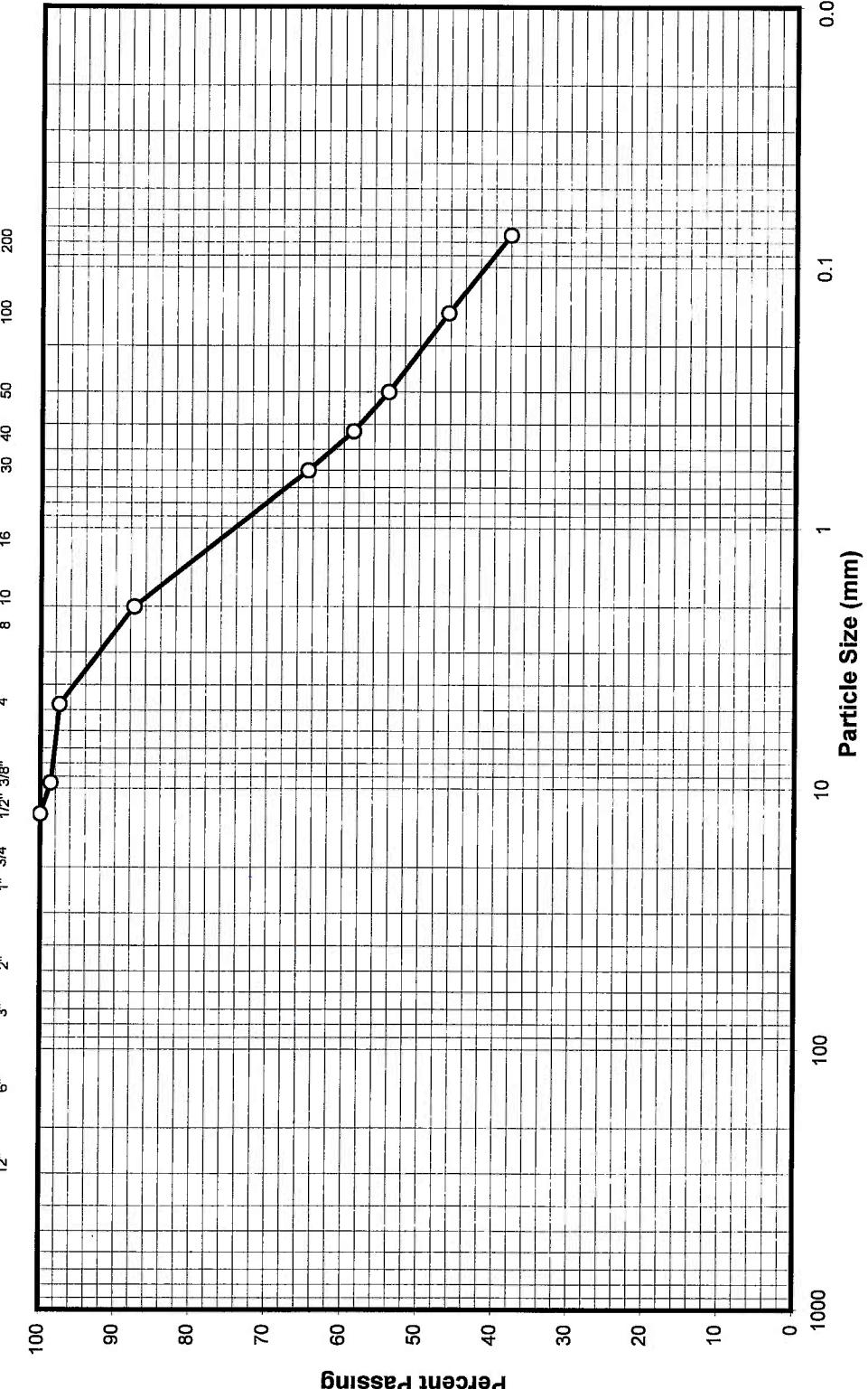
Gravel (%)	0	LL	37	Project Name:	Wichita Mountain nwr	<b>Yeh &amp; Associates, Inc.</b>	
Sand (%)	76	PL	20	Sample ID:	P - 6	Geotechnical Engineering Consultants	
Fines (%)	24	PI	17	Sample Depth (ft.):	4	<b>SIEVE ANALYSIS</b>	
Sample Description:	SC / A - 2 - 6 (0)		Drawn By:	MA	Project No.:	28 - 238	
			Checked By:	SY	Date:	12/03/08	Figure No.:

Sieve Analysis							Hydrometer Analysis	
				U.S. Standard Sieves			Size of Particles in mm	
Sieve Opening in Inches	12"	6"	3"	2"	1"	3/4"	1/2"	3/8"



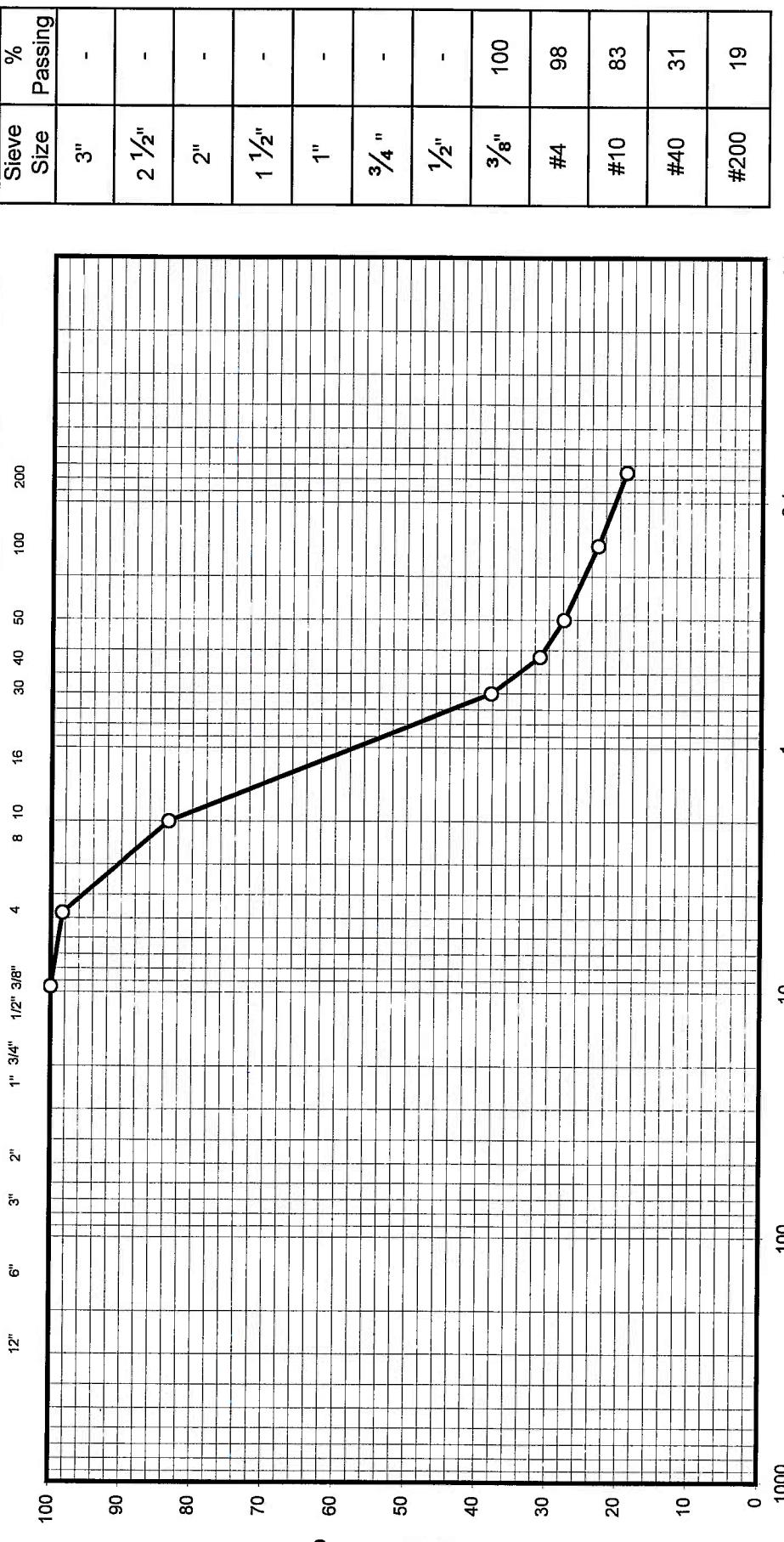
<b>Yeh &amp; Associates, Inc.</b> <small>Geotechnical Engineering Consultants</small>	<b>SIEVE ANALYSIS</b>	
	Drawn By:	MA
	Checked By:	SY
	Date:	11/07/08
Sample Description:	Project No.:	28 - 238
SC / A - 2 - 6 (1)	Figure No.:	-

Sieve Analysis						Hydrometer Analysis	
Sieve Opening in Inches			U.S. Standard Sieves			Size of Particles in mm	
12"	6"	3"	2"	1"	3/4"	1/2"	3/8"



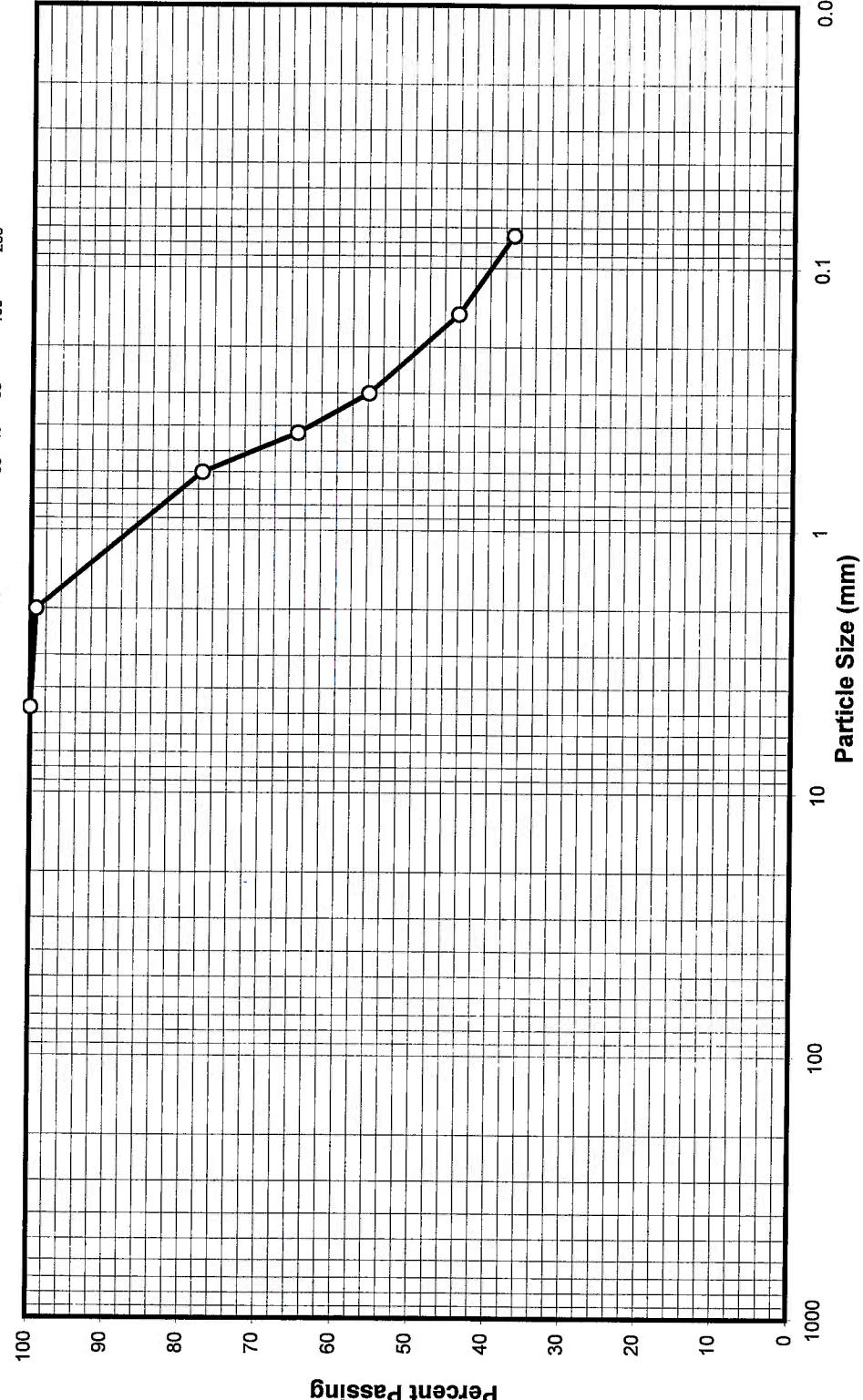
Gravel (%)	3	LL	29	Project Name:	Wichita Mountain nwr	<b>Y</b>	<b>Yeh &amp; Associates, Inc.</b>
Sand (%)	59	PL	20	Sample ID:	P - 8	Geotechnical Engineering Consultants	
Fines (%)	38	PI	9	Sample Depth (ft.):	1	<b>SIEVE ANALYSIS</b>	
Sample Description:	SC / A - 4 ( 0 )			Drawn By:	MA	Project No.:	28 - 238
				Checked By:	SY	Figure No.:	-
				Date:	12/03/08		

Sieve Analysis					
Sieve Opening in Inches			U.S. Standard Sieves		
12"	6"	3"	2"	1"	1/2" 3/8"
100	60	40	30	20	10



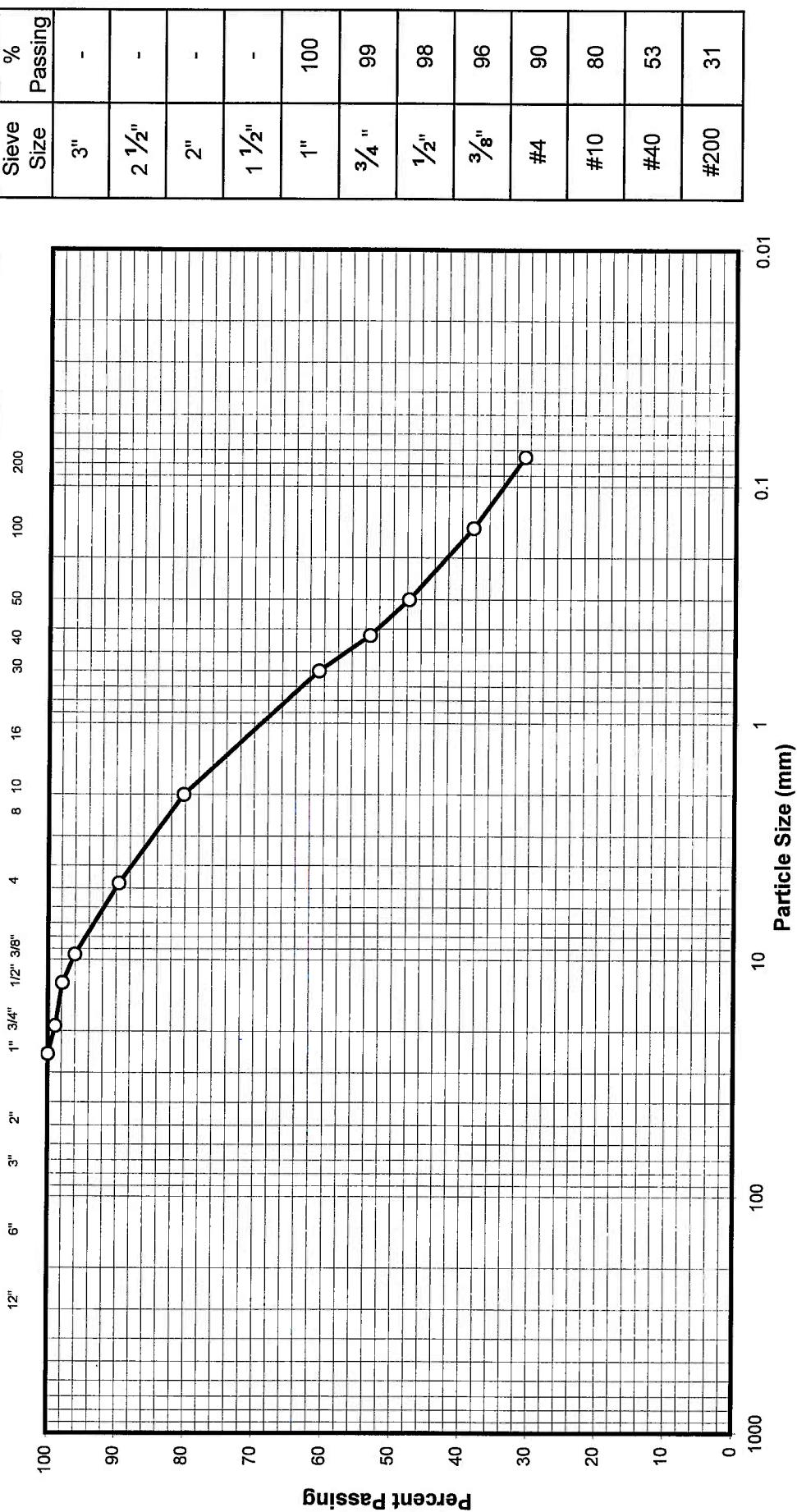
Wichita Mountain nwr				Yeh & Associates, Inc.			
Project Name:				Geotechnical Engineering Consultants			
Sample ID:	P - 10						
Sample Depth (ft.):	1						
Drawn By:	MA	Project No.:	28 - 238				
Checked By:	SY	Figure No.:	-				
Date:	12/03/08						
Sample Description:	SC / A - 2 - 6 (0)						

Sieve Analysis							Hydrometer Analysis	
Sieve Opening in Inches							U.S. Standard Sieves	
12"	6"	3"	2"	1"	3/4"	1/2"	3/8"	4
100								



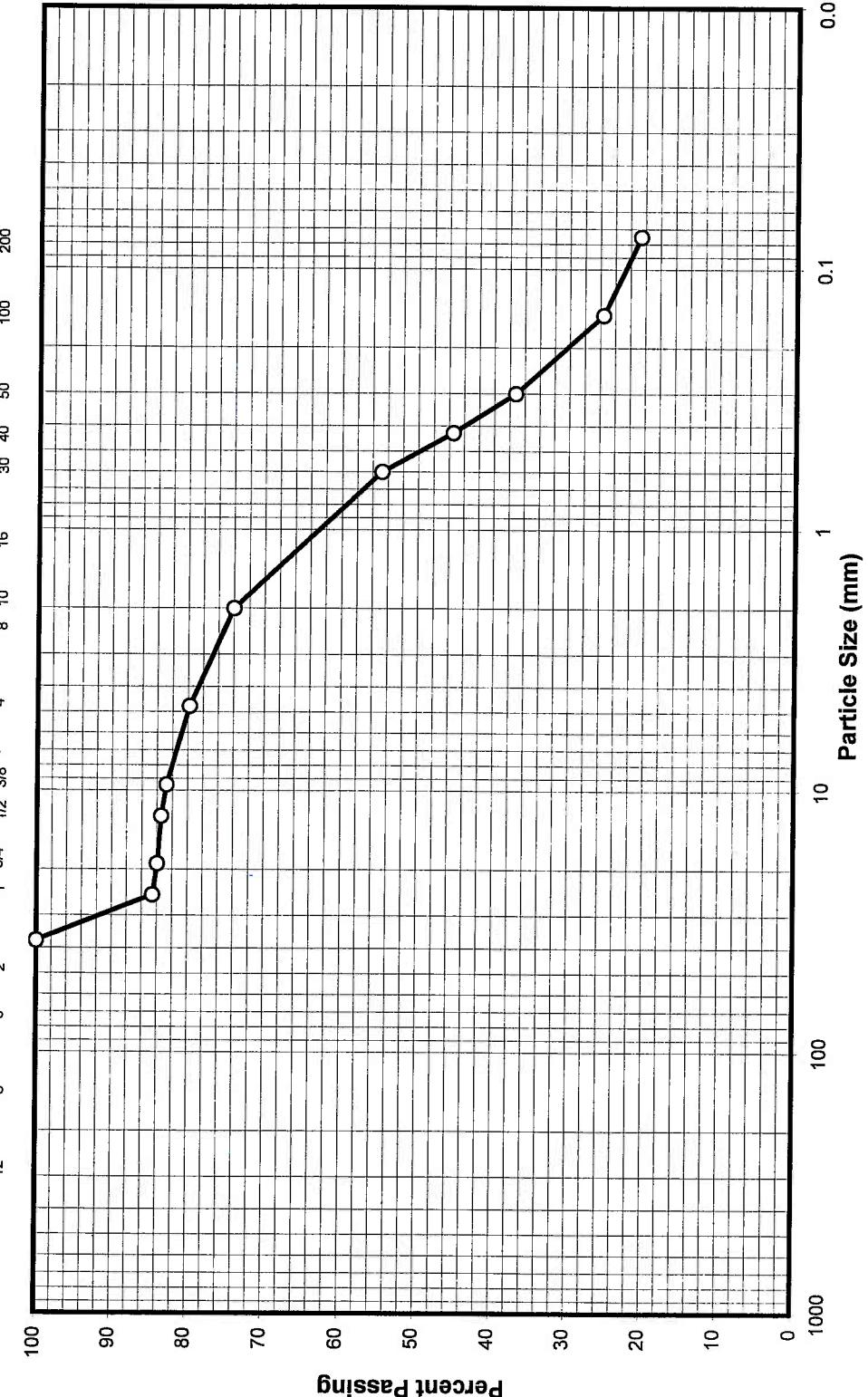
Gravel (%)	0	LL	40	Project Name:	Wichita Mountain nwr	<b>Yeh &amp; Associates, Inc.</b>	
Sand (%)	63	PL	20	Sample ID:	P - 12	Geotechnical Engineering Consultants	
Fines (%)	37	PI	20	Sample Depth (ft.):	4	<b>SIEVE ANALYSIS</b>	
Sample Description:	SC / A - 6 ( 3 )					Drawn By:	MA
						Checked By:	SY
						Date:	12/03/08
						Project No.:	28 - 238
						Figure No.:	-

Sieve Analysis						Hydrometer Analysis	
Sieve Opening in Inches			U.S. Standard Sieves			Size of Particles in mm	
12"	6"	3"	2"	1"	3/4"	1/2"	3/8"

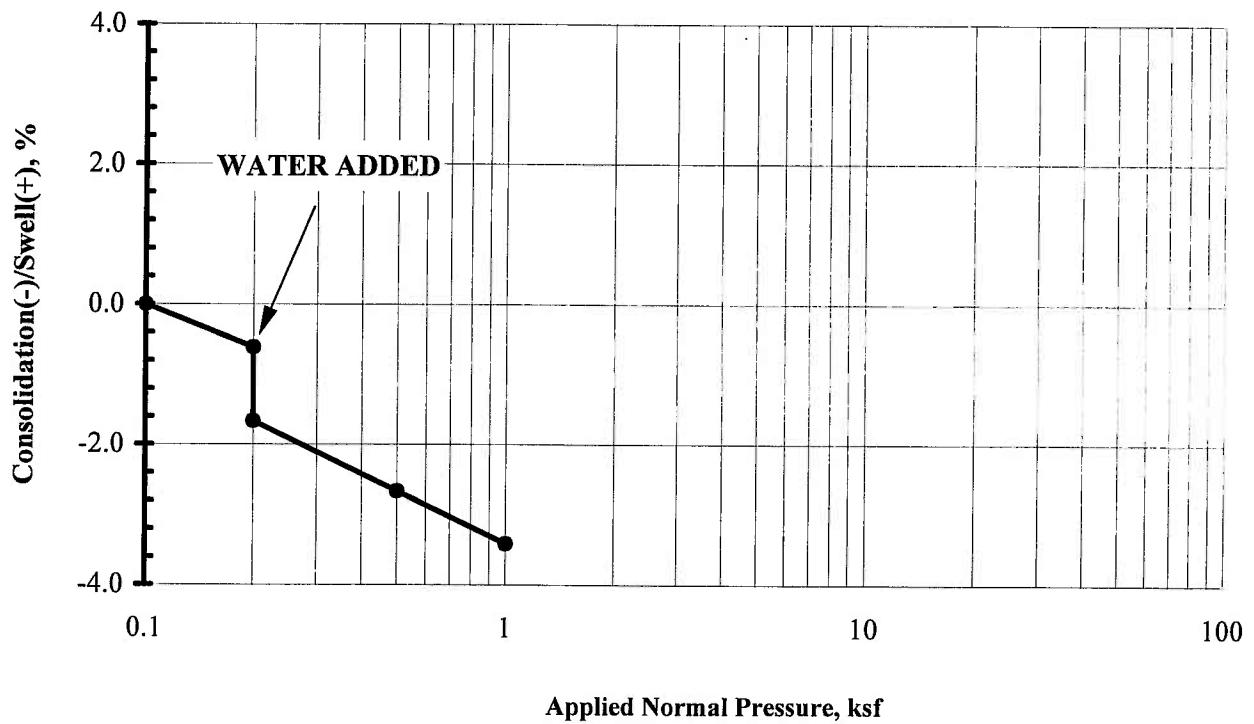


Gravel (%)	10	LL	29	Project Name:	Wichita Mountain nwr	<b>Y</b> <b>Yeh &amp; Associates, Inc.</b>	
Sand (%)	59	PL	16	Sample ID:	P - 13	Geotechnical Engineering Consultants	
Fines (%)	31	PI	13	Sample Depth (ft.):	0 - 5	<b>SIEVE ANALYSIS</b>	
Sample Description:	SC / A - 2 - 6 (0)					Drawn By: MA Checked By: SY Date: 11/07/08	Project No.: 28 - 238 Figure No.: -

Sieve Analysis							Hydrometer Analysis	
							Size of Particles in mm	
Sieve Opening in Inches	12"	6"	3"	2"	1"	3/4"	1/2"	3/8"
	100	90	80	70	60	50	40	30

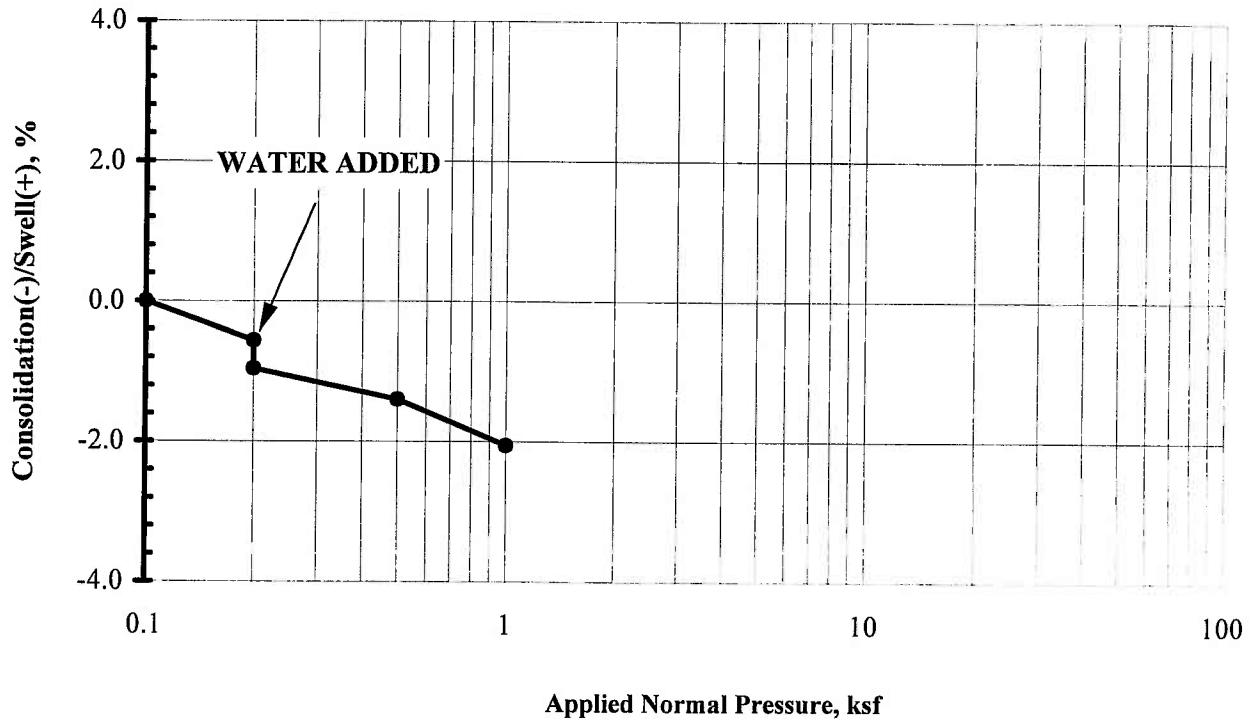


<b>Yeh &amp; Associates, Inc.</b> <small>Geotechnical Engineering Consultants</small>	<b>SIEVE ANALYSIS</b>	
	Drawn By:	MA
	Checked By:	SY
	Date:	12/03/08
Sample Description:	Project No.:	28 - 238
SM / A - 1 - b (0)	Figure No.:	-



Boring Number	Depth, ft	Natural Dry Density, pcf	Moisture Content, %	Consolidation(-)/Swell(+), %	Soil Description	SWELL / CONSOLIDATION GRAPH
P - 3	1	105.8	11.7	-1.1	clayey SAND	Drawn By: M.A
Job No:	28 - 238	Project Name:	Wichita Mountain NWR			Checked By: S.Y

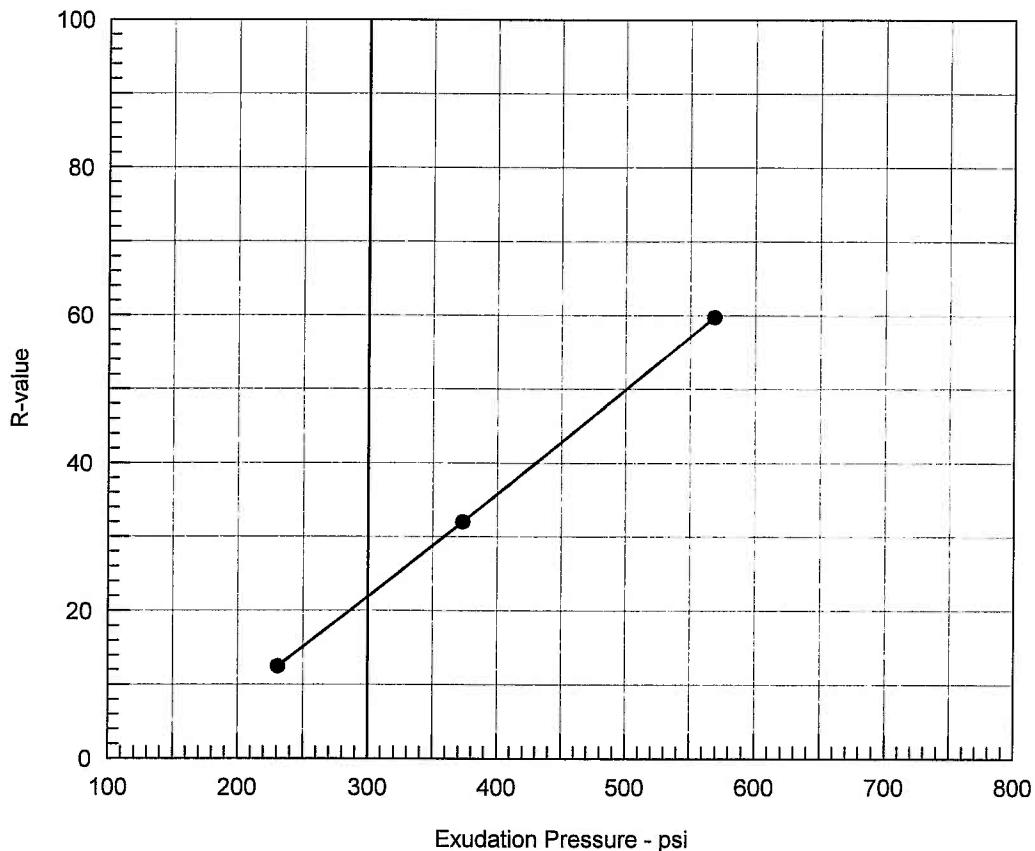
YEH & ASSOCIATES, INC



Boring Number	Depth, ft	Natural Dry Density,pcf	Moisture Content, %	Consolidation(-)/Swell(+), %	Soil Description	SWELL / CONSOLIDATION GRAPH
P - 7	1	103.6	13.8	-0.4	clayey SAND	Drawn By: M.A
Job No:	28 - 238	Project Name:	Wichita Mountain NWR			Checked By: S.Y

YEH & ASSOCIATES, INC

## R-VALUE TEST REPORT

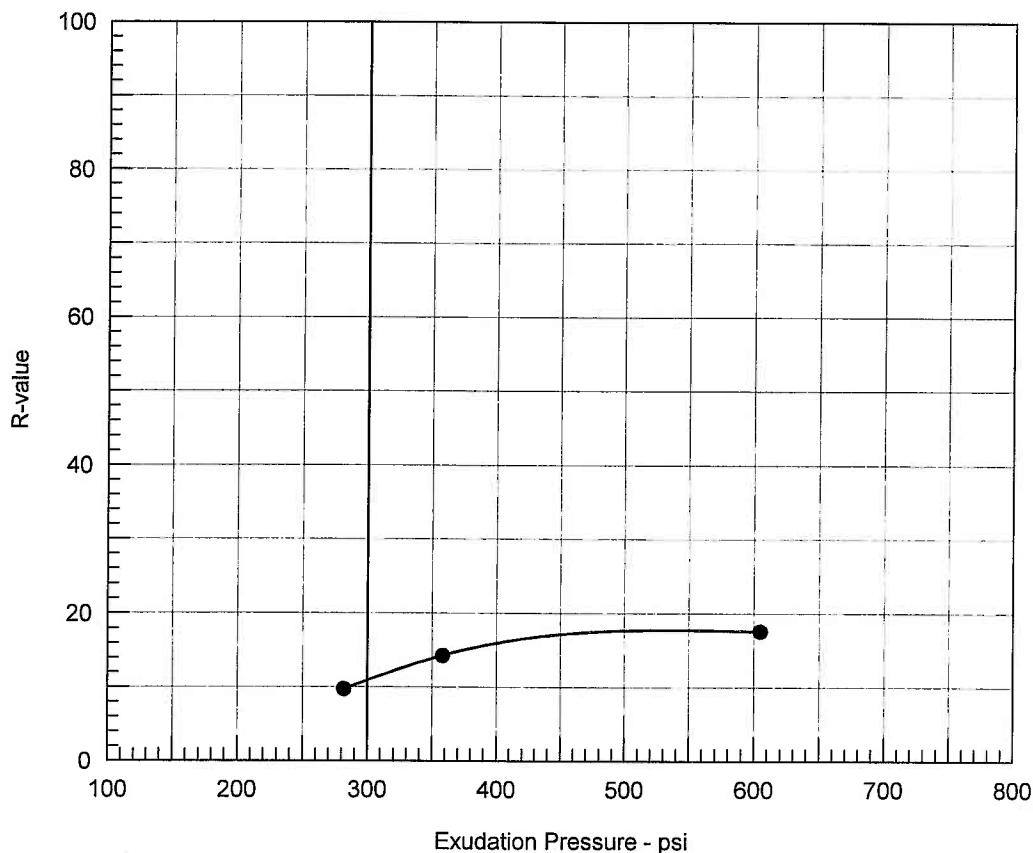


**Resistance R-Value and Expansion Pressure - AASHTO T 190**

No.	Compact. Pressure psi	Density pcf	Moist. %	Expansion Pressure psf	Horizontal Press. psi @ 160 psi	Sample Height in.	Exud. Pressure psi	R Value	R Value Corr.
1	160	112.7	13.5	0	130	2.48	231	12	12
2	280	115.6	11.4	0	97	2.53	373	32	32
3	350	115.6	10.6	0	53	2.53	569	60	60

Test Results		Material Description	
R-value at 300 psi exudation pressure = 22			
<b>Project No.:</b> M06.1071.000 <b>Project:</b> Yeh & Associates <b>Location:</b> #28-238, B-13 <b>Sample Number:</b> 4472-2 <b>Date:</b> 11/21/2008		<b>Tested by:</b> S. Tschida <b>Checked by:</b> H. Redzic <b>Remarks:</b> Index properties tested by Yeh & Associates	
<b>R-VALUE TEST REPORT</b> <b>Geocal, Inc.</b>		<b>Figure B-13</b>	

## R-VALUE TEST REPORT



**Resistance R-Value and Expansion Pressure - AASHTO T 190**

No.	Compact. Pressure psi	Density pcf	Moist. %	Expansion Pressure psf	Horizontal Press. psi @ 160 psi	Sample Height in.	Exud. Pressure psi	R Value	R Value Corr.
1	160	105.2	17.1	17	122	2.51	605	18	18
2	110	101.6	19.2	0	136	2.55	282	10	10
3	140	103.1	18.7	9	126	2.51	358	14	14

Test Results		Material Description
R-value at 300 psi exudation pressure = 11		
Project No.: M06.1071.000 Project: Yeh & Associates Location: #28-238, B-9 Sample Number: 4472-1 Date: 11/21/2008		<b>Tested by:</b> S. Tschida <b>Checked by:</b> H. Redzic <b>Remarks:</b> Index properties tested by Yeh & Associates
Depth: 0-5 feet <b>R-VALUE TEST REPORT</b> <b>Geocal, Inc.</b>		Figure B-9

## APPENDIX C

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### TRAFFIC INFORMATION

Traffic Loading Calculations  
Wichita Mountain Wildlife Area

1/2  
Yeh Project: 28-238

Traffic Loading	2009 <u>AADT</u>	2029 <u>AADT</u>	Assumptions:
Route 11	1240	1370	20-Year Growth Factor = 10%
Route 10	1750	1934	Annual Growth Factor = 0.50%

<u>Vehicle Type &amp; ESAL Factor</u>	<u>% of volume</u>	<u>ESAL Factor</u>	<u>V1 &amp; V2 Classification</u>
Passenger Cars and Pick-ups	90%	0.0004	2
2-axle SU (RVs)	4%	0.5	5
3-axle SU Trucks	1%	1.5	6
Busses	5%	0.88	4

**20-Year ESAL Calculation = 20-Year Design Loading**

Design Volume = (2009 volume + 2029 volume)/2

Route 11 Design AADT = 1305  
Route 10 Design AADT = 1842

**Rte 10**

**Total ESAL Loading = Design Volume X ESAL factors X 365 days/year X 20 years**

Route 10 Design Volume =	1842	Passenger Cars = 90% X	1842 veh/da X	365 days/ yr X	20 X ESAL fac	0.0004 years =	4841 ESALS
2-axle SU (RVs)	4% X	1842 veh/da X	365 days/ yr X	20 X ESAL fac	0.5 years =	268932 ESALS	
3-axle Trucks	1% X	1842 veh/da X	365 days/ yr X	20 X ESAL fac	1.5 years =	201699 ESALS	
Busses	5% X	1842 veh/da X	365 days/ yr X	20 X ESAL fac	0.88 years =	591650 ESALS	

Lane Correction Factor for two lane Road =

0.6 (Approximately half in each direction)  
Shoulder Design ESALS (only 10% of vehicles drive on the shoulders)

Rte 10 Shoulder 20-Year ESALs =

640273 ESALS

Total 20-Year ESALs= 1067122

Driving Lane 20-Year Design ESALs =

640273 ESALS

Rte 10 Shoulder 20-Year ESALs =

640273 ESALS

**Rte 11****Total ESAL Loading = Design Volume X ESAL factors X 365 days/year X 20 years**

Route 10 Design Volume =	1305						
Passenger Cars =	90%	X	1305	veh/da X	365	days/ yr X	20
2-axle SU (RVs)	4%	X	1305	veh/da X	365	days/ yr X	20
3-axle Trucks	1%	X	1305	veh/da X	365	days/ yr X	20
Busses	5%	X	1305	veh/da X	365	days/ yr X	20

Lane Correction Factor for two lane Road =

0.6 (Approximately half in each direction)

Shoulder Design ESALs

(only 10% of vehicles drive on the shoulders)

Total 20-Year ESALs=

756023

Driving Lane 20-Year Design ESALs =

453614 ESALs

Rte 11 Shoulder 20-Year ESALs =

45361 ESALs

## APPENDIX D

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### PAVEMENT DESIGNS

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product  
Flexible Structural Design Module

Wichita Mountains National Wildlife Refuge  
28-238  
Full Depth Asphalt  
Route 10

### Flexible Structural Design

18-kip ESALs Over Initial Performance Period	64,027
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1
Calculated Design Structural Number	2.48 in

### Specified Layer Design

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width (ft)	Calculated <u>SN (in)</u>
1	Full Depth HACP	0.4	1	6.25	12	2.50
Total	-	-	-	6.25	-	2.50

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product  
Flexible Structural Design Module

Wichtia Mountains National Wildlife Refuge  
28-238  
Composite with ABC  
Route 10

**Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	64,027
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1
Calculated Design Structural Number	2.48 in

**Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated <u>SN (in)</u>
1	ABC Class 6	0.14	1	9	12	1.26
2	HACP	0.4	1	3	12	1.20
Total	-	-	-	12.00	-	2.46

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product

Flexible Structural Design Module

Wichtia Mountains National Wildlife Refuge  
28-238  
Composite with ABC 2  
Route 10

**Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	64,027
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1
Calculated Design Structural Number	2.48 in

**Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated <u>SN (in)</u>
1	ABC Class 6	0.14	1	8	12	1.12
2	HACP	0.4	1	3.5	12	1.40
Total	-	-	-	11.50	-	2.52

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product

Flexible Structural Design Module

Wichita Mountain Wildlife Refuge  
28-238  
Composite Design  
Route 10

**Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	64,027
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1

Calculated Design Structural Number                    2.48 in

**Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated <u>SN (in)</u>
1	Select Borrow R>55	0.08	1	12	12	0.96
2	ABC Class 6	0.14	1	4	12	0.56
3	HACP	0.4	1	2.5	12	1.00
Total	-	-	-	18.50	-	2.52

1993 AASHTO Pavement Design  
**DARWin Pavement Design and Analysis System**  
A Proprietary AASHTOWare  
Computer Software Product  
Flexible Structural Design Module

Wichita Mountain Wildlife Refuge  
28-238  
Composite and Full Depth  
Mainline Patch Thickness  
Route 10

### **Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	640,273
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1
Calculated Design Structural Number	3.62 in

### **Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated SN (in)
1	ABC Class 6	0.14	1	6	12	0.84
2	HACP	0.4	1	7	12	2.80
Total	-	-	-	13.00	-	3.64

### **Layered Thickness Design**

<u>Layer</u>	<u>Material Description</u>	Actual						Calculated SN (in)
		Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Spec Thickness <u>(Di)(in)</u>	Min Thickness <u>(Di)(in)</u>	Elastic Modulus <u>(psi)</u>	Width <u>(ft)</u>	
1	Full Depth HMA	0.4	1	-	-	-	-	9.05
Total	-	-	-	-	-	-	-	9.05

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product

**Flexible Structural Design Module**

Wichita Mountains National Wildlife Refuge  
28-238  
Full Depth Asphalt  
Route 11

**Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	45,361
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1
Calculated Design Structural Number	2.34 in

**Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated SN (in)
1	Full Depth HACP	0.4	1	6	12	2.40
Total	-	-	-	6.00	-	2.40

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product

Flexible Structural Design Module

Wichita Mountain Wildlife Refuge  
28-238  
Composite with ABC  
Route 11

**Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	45,361
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1

Calculated Design Structural Number                    2.34 in

**Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width (ft)	Calculated SN (in)
1	ABC Class 6	0.14	1	9	12	1.26
2	HACP	0.4	1	3	12	1.20
Total	-	-	-	12.00	-	2.46

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product

Flexible Structural Design Module

Wichtia Mountains National Wildlife Refuge  
28-238  
Composite with ABC 2  
Route 11

**Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	45,361
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1

Calculated Design Structural Number                    2.34 in

**Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated SN (in)
1	ABC Class 6	0.14	1	7	12	0.98
2	HACP	0.4	1	3.5	12	1.40
Total	-	-	-	10.50	-	2.38

1993 AASHTO Pavement Design  
DARWin Pavement Design and Analysis System  
A Proprietary AASHTOWare  
Computer Software Product

**Flexible Structural Design Module**

Wichita Mountain National Wildlife Refuge  
28-138  
Route 11

**Flexible Structural Design**

18-kip ESALs Over Initial Performance Period	45,361
Initial Serviceability	4.2
Terminal Serviceability	2.5
Reliability Level	75 %
Overall Standard Deviation	0.49
Roadbed Soil Resilient Modulus	4,334 psi
Stage Construction	1
Calculated Design Structural Number	2.34 in

**Specified Layer Design**

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated <u>SN (in)</u>
1	Select Borrow	0.08	1	10	12	0.80
2	ABC Class 6	0.14	1	4	12	0.56
3	HACP	0.4	1	2.5	12	1.00
Total	-	-	-	16.50	-	2.36

**APPENDIX E**

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**COST ANALYSIS DATA**

## Appendix E

### Treatment Options and Costs

#### Wichita Mountains WLF

Given:      **HMA =**  
**ABC Class 6 =**  
**Select Borrow =**

Costs from Oklahoma DOT web page for 2009 projects

    \$70.00 /ton  
 \$42.00 /yd3  
 \$25.00 /ft3

=>

<b>HACP =</b>	145	#/ft3
<b>HACP =</b>	110	#/yd2-inch
<b>ABC =</b>	139	#/ft3
<b>Select Borrow =</b>	125	#/ft3

#### HMA

<u>Thickness</u>	<u>Tons/yd2</u>	<u>\$/yd2</u>	<u>ABC</u>	<u>Thickness</u>	<u>yd3 /yd2</u>	<u>\$/yd2</u>	<u>Select Borrow</u>	<u>Thickness</u>	<u>yd3 /yd2</u>	<u>\$/yd2</u>
2.5	0.138	\$9.63		4	0.111	\$4.67		8	0.222	\$5.56
3	0.165	\$11.55		7	0.194	\$8.17		10	0.278	\$6.94
3.5	0.193	\$13.48		8	0.222	\$9.33		12	0.333	\$8.33
6	0.330	\$23.10		9	0.250	\$10.50		14	0.389	\$9.72
6.25	0.344	\$24.06		10	0.278	\$11.67				

#### Individual Treatment Costs per Square Yard

<u>Route</u>	<u>HMA</u>	<u>HMA Cost</u>	<u>ABC</u>	<u>Thickness</u>	<u>ABC Cost</u>	<u>Select Borrow</u>	<u>Thickness</u>	<u>ABC Cost</u>	<u>Select Borrow</u>	<u>Thickness</u>	<u>ABC Cost</u>	<u>Total Treatment Cost</u>
10	Full Depth HACP	6.25	\$24.06	0.0	\$0.00	0.0	0.0	\$0.00	0.0	0.0	\$0.00	\$24.06
10	HACP + ABC #1	3.0	\$11.55	10.0	\$11.67	0.0	0.0	\$0.00	0.0	0.0	\$0.00	\$23.22
10	HACP + ABC #2	3.5	\$13.48	8.0	\$9.33	0.0	0.0	\$0.00	0.0	0.0	\$0.00	\$22.81
10	HACP+ABC+Select	2.5	\$9.63	4.0	\$4.67	12.0						\$22.63
11	Full Depth HACP	6.0	\$23.10	0.0	\$0.00	0.0	0.0	\$0.00	0.0	0.0	\$0.00	\$23.10
11	HACP + ABC #1	3	\$11.55	9.0	\$10.50	0.0	0.0	\$0.00	0.0	0.0	\$0.00	\$22.05
11	HACP + ABC #2	3.5	\$13.48	7.0	\$8.17	0.0	0.0	\$0.00	0.0	0.0	\$0.00	\$21.64
11	HACP+ABC+Select	2.5	\$9.63	4.0	\$4.67	10.0						\$21.24